

BELLCOMM, INC.

955 L'ENFANT PLAZA NORTH, S.W.

WASHINGTON, D.C. 20024

869 04085

SUBJECT: Forward Propagation Characteristics
of Apollo 8 and LL03 Trajectory
Solutions - Case 310

DATE: April 22, 1969
FROM: J. T. Findlay
M. G. Kelly

ABSTRACT

Forward propagation characteristics of single orbit, multiple station trajectory solutions for Apollo 8 and Lunar Orbiter (LL03) have been evaluated. Trajectory propagation errors were found to be usefully consistent when single arc ODP (Orbit Determination Program) state vectors were extrapolated forward one, two and three orbits and compared to the respective local arc solution. Deviations in local vertical coordinates are presented graphically and summarized in tabular form. Apollo 8 forward propagation errors are also presented graphically in the Selenocentric Mean of 1950 inertial frame. In all cases both the trajectory solutions and the forward propagation procedure utilized a triaxial lunar potential model.

The results indicate that navigation accuracy for Apollo can be improved by an empirical method. This method would require off-line processing in the RTCC to ascertain trends in state error propagation by comparing a sequence of adjacent arc ODP vectors. Consistent trends would allow improved state prediction in that the propagated vector could be biased to account for the trend. Apollo 8 results indicate that navigation accuracies of +5000 feet in position and +5 fps in velocity could thus be realized. These accuracies were further substantiated by some of the LL03 results which is encouraging since LL03 was essentially an Apollo type orbit.

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CHARACTERISTICS OF APOLLO 8 AND LL03
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MEMORANDUM FOR FILE

INTRODUCTION

The navigation technique presently proposed for Apollo during lunar parking orbit consists of processing single orbit Doppler data in RTCC from four MSFN stations selected to maximize the tracking geometry. Whereas it is true that single arc ODP solutions best minimize the Doppler residuals in the fit region, previous studies have shown that this type of solution does not always propagate well.

This study was undertaken to determine the consistency between single arc ODP solutions for successive orbits. If, when any particular solution is propagated a prescribed number of orbits and compared to that current solution, the differences between these state vectors throughout the current arc are essentially the same regardless of the epochs selected, then the ODP solutions may be described as "consistent in terms of forward propagation". If the ODP solutions do possess this property, it would be possible to bias the predicted estimate of state to improve navigation in lunar orbit. Therefore the estimated state, which is an extrapolation of a local solution obtained on some previous arc, could be improved consequently minimizing navigation errors. The underlying assumption herein is that the current arc solution most nearly represents the "actual" spacecraft trajectory.

PROCEDURAL DISCUSSION

Apollo 8 and Lunar Orbiter (LL03) state vectors presented in References 1 and 2 were used to conduct the study. The Apollo 8 state vectors (Reference 1) were actual RTCC vectors obtained during the C' Mission. Of particular importance were the vectors in lunar parking orbit, REVS 3 through 10. The processing epochs for these solutions were essentially one orbit apart and each was anchored at the approximate time the spacecraft emerged from occultation. REV 3 was taken as the first orbit since it corresponds to the first circular orbit.

Each of the states is the result of single-orbit, multi-station processing. Each state was propagated forward and compared to the local solution one, two and three orbits later where possible. The comparisons were made in both local vertical and inertial Selenocentric Mean of 1950 coordinates with the current local solution considered to be correct when forming the differences. The local vertical coordinate frame is defined as U (vertical), V (downrange) and W (out-of-plane). Also generated were altitude, latitude and longitude differences. The results are presented as plots of (propagated-local) errors extending over three complete orbits.

The LL03 vectors were valid during two tracking periods, September 11-12 and October 5-6. Again, these vectors were derived by processing single arc, multi-station data. Data from both DSN and MSFN were used in the ODP solutions. Forward propagation procedures for LL03 were the same as those outlined for Apollo 8 but only local vertical coordinates were considered.

DISCUSSION OF RESULTS

Apollo 8

Figures 1-14 show the forward propagation results obtained for Apollo 8. Curves designated by a given number, N, reflect the errors between the Nth arc ODP solution propagated the designated number of orbits and the current local solution.

Figures 1-3 show U, V and W errors obtained by integrating single orbit ODP solutions and comparing them with local solutions obtained one, two and three orbits later where possible. Figures 4-6 are the local vertical velocity component errors for one, two and three orbits of prediction respectively. Finally, Figures 7-9 show altitude, latitude and longitude deviations for the same time periods. Figures 10-12 are composites of the information contained in Figures 1-9. The jump discontinuity between orbits, most noticeable from the composite plots, are the direct result of comparing the propagated vector to the current local solution, which is obviously different for different arcs. These discontinuities are not unique to Apollo 8 but are also evident in the LL03 results.

Figures 13 and 14 are the analogues of Figures 10 and 11 in inertial coordinates. The errors in the inertial frame are also consistent but give less information about the distribution of the errors relative to the orbital plane than the local vertical plots. The local vertical plots show a lack of systematic bias in the out-of-plane position and velocity and discourage biasing of those quantities. Basing the biases on inertial coordinate error tendencies must incorporate special treatment to eliminate out-of-plane errors. The best biasing technique is not yet determined.

Table I summarizes the Apollo 8 forward propagation results in local vertical coordinates. Peak-to-peak deviations and the maximum spreads between the curves are tabulated for one, two and three orbit predictions. The peak-to-peak variations represent state estimation errors if no empirical corrections are made. The spreads can be construed as the improvement in prediction accuracy that can be achieved if the estimated state is offset according to the propagation trends established.

The second ODP solution (Rev 4) appears to be bad, particularly in the plane definition. Even considering this orbit some reasonable in-plane trends can be established. Vertical position deviations of as much as ± 2000 feet can be seen in Table I when comparing adjacent arc ODP states. By biasing the estimated vertical position component along some average curve the uncertainty can be reduced to ± 500 feet. The peak-to-peak radial deviations for 2 and 3 orbit propagation are ± 4000 and ± 5500 feet respectively. Again, assuming some mean curve to be applicable, these deviations can be reduced to ± 400 and ± 600 feet.

Downrange position estimation accuracy can be improved to within ± 4000 , ± 2500 and ± 4500 feet respectively for one, two and three orbits of propagation. These numbers are down from the otherwise uncorrected peak deviations of -17000 , -36000 and -56000 feet. It is noteworthy that the local state estimate is always downrange of the propagated vector, i.e., leading it. This is indicative of a period error and thus a true anomaly shift.

In-plane velocity components show variations of 7-14 fps in \dot{U} and ± 1.7 fps in \dot{V} when the single arc ODP solutions are compared to the local solutions in the adjacent arc. These

numbers can be improved to ± 3.5 fps for \dot{U} and ± 0.4 fps for \dot{V} . Also, the dispersions for 2 and 3 orbit predictions, the peak values of which increase linearly with the number of propagated arcs to as much as 45 fps in \dot{U} and 5 fps in \dot{V} , can be reduced to within ± 3.5 fps (\dot{U}) and ± 0.5 fps (\dot{V}). Actually \dot{U} accuracies of ± 2.3 fps for the two-orbit prediction were obtained.

Altitude prediction can be obtained to essentially the same accuracy as the radial position component. The altitude (and radial position) deviations show increasing amplitudes with the number of orbits propagated. This is indicative of a ramped variation in eccentricity. Thus improved state estimation could conceivably be better when individually offsetting state components (or orbital elements) rather than merely biasing the time tag of the state vector (which effects only a true anomaly lift).

Neglecting the second orbit (Rev 4), out-of-plane accuracies of ± 3000 feet and ± 2.5 fps for position and velocity respectively can be achieved.

Latitude and longitude uncertainties of ± 0.03 degrees and ± 0.04 degrees are feasible when comparing any two adjacent arc ODP solutions. Prediction accuracies are essentially the same when two orbit propagated states are compared to local arc values with some increase in the inaccuracies evident for the three arc predicted values as can be seen in Table I.

When Rev 4 is considered, the out-of-plane position and velocity uncertainties increase to ± 13000 feet and ± 12 fps, with a corresponding increase in latitude inaccuracy to approximately ± 0.13 degrees. These values are dominated by the lack of consistency between the vectors for orbits 1 and 2 (Revs 3 and 4). The ODP solutions for these two arcs resulted in the maximum excursion for orbital inclination observed over the whole C' Mission, 167.65° for Rev 3 and 167.76° for Rev 4.

Lunar Orbiter

Figures 15 through 32 depict the forward propagation characteristics of single arc ODP solutions in local vertical coordinates obtained for the low orbit phase of LO III. Figures 15-17 (24-26) show the deviation in the position components for the September 11-12 (October 5-6) tracking periods. The velocity

deviations are given in Figures 18-20 (27-29). Finally altitude, latitude and longitude variations are presented in Figures 21-23 (30-32) for the same two tracking periods.

The September curves show larger amplitudes and spreads than those for October. One possible explanation for this is that the first two September state vectors used were derived from single orbit ODP processing which included only DSN data from Woomera and Madrid. This results in poorer tracking geometry than the other ODP solutions which incorporated the MSFN stations in the solution. All state vectors used for October were based on ODP solutions which did utilize the available DSN and MSFN tracking coverage.

Table II summarizes the results obtained using the September state vectors and Table III presents the results corresponding to the October 5-6 period.

For the September period orbit #1 appears bad, again in the definition of the orbital plane. Unlike Apollo 8, when this orbit is considered the plane inconsistency couples into the downrange error. Disregarding the first orbit, U, V and W position accuracies of +1200, +12000 and +15000 feet can be achieved. The corresponding velocity accuracies are +10, +0.5 and +12 fps. Essentially the same accuracies can be attained for the two and three orbit predictions. As can be seen from Table II, an empirical technique based on the September results does not significantly improve the prediction capability for the adjacent arc, however, a significant percentage improvement in prediction accuracy can be achieved when predicting ahead further than one orbit. A noticeable difference with the LL03 data is the improved consistency of plane definition between an ODP solution propagated ahead 3 orbits and a current local solution for that arc.

As shown in Table II it is possible to predict the altitude of the spacecraft to within +1200 feet. Also, the sub-vehicle point latitude and longitude can be predicted to approximately +0.15° and +0.09°. These numbers are based on comparing two adjacent arcs but the accuracies do not appear to degrade for the two and three orbit predictions.

As shown in Table III the October LL03 results show marked improvement over those for September. The seventh orbit for the October period resulted in essentially twice the downrange propagation error than that obtained for the other orbits and therefore was not considered when developing Table III. Disregarding this orbit the October LL03 results are even more consistent than Apollo 8. However, the Apollo 8 results would show some improvement if both Revs 3 and 4 were disregarded.

For October, local vertical position and velocity components after one orbit can be predicted to within ± 500 feet in U , ± 3000 feet in V , ± 6000 feet in W , ± 2 fps in \dot{U} , ± 0.4 fps in \dot{V} and ± 4.5 fps in \dot{W} . Altitude prediction accuracies of ± 600 feet could be expected with latitude and longitude uncertainties of $\pm 0.05^\circ$ and ± 0.025 , respectively. These values are based on single orbit prediction.

SUMMARY AND RECOMMENDATIONS

State prediction for Apollo 8 and LL03 has been looked at in detail. Single arc ODP solutions were propagated one, two and three orbits beyond the fit region resulting in trends that, if utilized, yield significant improvement in state estimation. Apollo 8 results show evidence of possible improved position and velocity accuracies of ± 5000 feet and ± 5 fps. October results for LL03 give essentially the same accuracies, which is further proof of the feasibility of such an empirical method. If single arc, multi-station ODP solutions* are used in the Apollo RTCC for MSFN navigation it is recommended that such an empirical method be employed off-line. This does not imply that empirical trends could not be established for multi-arc processing. If an empirical technique is to be used some additional orbits would have to be available in the G Mission timeline to provide more single arc ODP solutions for comparison to enable the establishment of forward propagation trends. This would require the spacecraft to be in attitude hold during the astronauts' sleep cycle or the addition of some orbits in the timeline. A minimum of five consecutive ODP solutions is felt necessary.

Using trends established essentially in real time the navigation accuracy at Descent Orbit Insertion (DOI) could be improved. For example, Apollo 8 results indicate possible navigation accuracies (based on an approximate DOI time for an eastward landing site) at DOI of ± 500 feet, ± 2300 feet and ± 2000 feet for U , V , and W , respectively. Corresponding velocity accuracies of ± 2.3 , ± 0.35 and ± 2 for \dot{U} , \dot{V} and \dot{W} could be expected.

*The authors are not yet convinced that single arc processing is optimum. In fact, quite to the contrary, some results generated previously showed that ODP solutions based on two revolutions extrapolate much better outside the fit region than the single arc solutions.

There are three possible navigation vectors at DOI that could be used. First, assuming that no empirical methods are employed, the DOI vector would merely be an extrapolation of the latest available ODP solution. This would entail predicting ahead approximately 1 1/2 orbits. The results of this study indicate unacceptable navigation errors when local solutions based on a single arc are extrapolated this far beyond the fit region. The remaining two DOI vector possibilities would result from the empirical method. One approach would be to bias off the in-plane state components. The other approach would be merely a re-time tagging of the DOI state to effect a downrange anomaly shift. Obviously the best attainable vector at DOI would be the one in which the state components are updated. Because of the error growth when propagating from DOI to PDI, the simple anomaly shift at DOI cannot be ruled out. Further studies are necessary to define the best approach.

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MGK

Attachments: Tables I-III
Figures 1-32

BELLCOMM, INC.

REFERENCES

1. "Summary of Tracking Information for C'Mission (Apollo 8)";
U. S. Government Memorandum; FS/Chief, Flight Support
Division; January 7, 1969.
2. "LL03 State Vectors and 3-Way Doppler Bias Bolutions";
TRW Interoffice Correspondence; P. Norris; October 7, 1968.

TABLE I

FORWARD PROPAGATION RESULTS
APOLLO 8

		DIFFERENCES						>		
No. of Arcs Propagated		U (Feet)	V (Feet)	W (Feet)	\dot{U} (fps)	\dot{V} (fps)	\dot{W} (fps)	Alt. (Feet)	Lat. (deg)	Long. (deg)
1	a	(± 2000)	$\begin{pmatrix} -6000 \\ -17000 \end{pmatrix}$	(± 5000)	(7-14)	(± 1.7)	± 4.5	(± 2000)	(± 0.04)	$\begin{pmatrix} 0.06 \\ 0.17 \end{pmatrix}$
	b	± 500	± 4000	± 3000	± 3.5	± 0.4	± 2.5	± 600	± 0.03	± 0.04
2	a	(± 4000)	$\begin{pmatrix} -18000 \\ -36000 \end{pmatrix}$	(± 4000)	(19-28)	(± 3.5)	(± 3.5)	(± 4000)	(± 0.08)	$\begin{pmatrix} 0.18 \\ 0.34 \end{pmatrix}$
	b	± 400	± 2500	± 3000	± 2.3	± 0.3	± 2.8	± 450	$\pm .035$	± 0.025
3	a	(± 5500)	$\begin{pmatrix} -30000 \\ -56000 \end{pmatrix}$	(± 9000)	(31-45)	(± 5)	(± 8.0)	(± 5500)	(± 0.12)	$\begin{pmatrix} 0.28 \\ 0.53 \end{pmatrix}$
	b	± 600	± 4500	± 5500	± 3.5	± 0.5	± 5.0	± 600	± 0.025	± 0.04

*(a) Peak-to-Peak Variations Over the Orbit

(b) Maximum Spread Between Curves

NOTE: SECOND ORBIT (REV 4) WAS NOT CONSIDERED WHEN
EVALUATING \dot{W} , \dot{W} AND LAT DATA

TABLE II
 FORWARD PROPAGATION RESULTS
 LL03: September 11-12, 1967

		DIFFERENCES								
No. of Arcs Propagated		U (Feet)	V (Feet)	W (Feet)	\dot{U} (fps)	\dot{V} (fps)	\dot{W} (fps)	(Feet)	Lat. (deg)	Long. (deg)
1	a	(± 2000)	$\begin{pmatrix} +5000 \\ -20000 \end{pmatrix}$	(± 15000)	$\begin{pmatrix} -17 \\ -4 \end{pmatrix}$	$\begin{pmatrix} 1.3 \\ -1.6 \end{pmatrix}$	(± 12)	(± 2000)	(± 0.2)	$\begin{pmatrix} +0.03 \\ -0.17 \end{pmatrix}$
	b	± 1200	± 12000	± 15000	± 10	± 0.5	± 12	± 1200	± 0.15	± 0.09
2	a	(± 3500)	$\begin{pmatrix} +5000 \\ -33000 \end{pmatrix}$	(± 18000)	$\begin{pmatrix} -3 \\ 27 \end{pmatrix}$	$\begin{pmatrix} +2.5 \\ -2.5 \end{pmatrix}$	(± 15)	(± 3500)	(± 0.22)	$\begin{pmatrix} +0.04 \\ -0.30 \end{pmatrix}$
	b	± 1900	± 16000	± 15000	± 13	± 0.75	± 12.5	± 1900	± 0.17	± 0.13
3	a	(± 4000)	$\begin{pmatrix} -3000 \\ -37000 \end{pmatrix}$	(± 4000)	($6-26$)	$\begin{pmatrix} +3.5 \\ -3 \end{pmatrix}$	(± 3)	(± 4000)	(± 0.13)	$\begin{pmatrix} -0.02 \\ -0.34 \end{pmatrix}$
	b	± 1200	± 10000	± 1500	± 9	± 1	± 1.5	± 1200	± 0.04	± 0.1

* (a) Peak to Peak Variations Over the Orbit
 (b) Maximum Spread Between Curves

NOTE: FIRST ORBIT NOT CONSIDERED

TABLE III
FORWARD PROPAGATION RESULTS
LL03: October 5-6, 1967

		DIFFERENCES								
No. of Arcs Propagated		U (Feet)	V (Feet)	W (Feet)	\dot{U} (fps)	\dot{V} (fps)	\dot{W} (fps)	Alt. (Feet)	Lat. (deg)	Long. (deg)
1	a	(+900)	$\begin{pmatrix} -3500 \\ -12000 \end{pmatrix}$	(± 6000)	(3-9)	$\begin{pmatrix} +0.7 \\ -0.7 \end{pmatrix}$	$\begin{pmatrix} +5 \\ -5 \end{pmatrix}$	(± 1000)	(± 0.07)	$\begin{pmatrix} -.03 \\ -.11 \end{pmatrix}$
	b	± 500	± 3000	± 6000	± 2	± 0.4	± 4.5	± 600	± 0.05	$\pm .025$
2	a	(+1800)	$\begin{pmatrix} -10000 \\ -18000 \end{pmatrix}$	(± 3500)	(7-14)	$\begin{pmatrix} +1 \\ -1 \end{pmatrix}$	$\begin{pmatrix} 2.8 \\ -2.7 \end{pmatrix}$	(± 1800)	(± 0.075)	$\begin{pmatrix} -.07 \\ -.18 \end{pmatrix}$
	b	± 400	± 1800	± 2900	± 1.5	± 0.2	± 2.25	± 300	± 0.03	± 0.02
3	a	(+3000)	$\begin{pmatrix} -12000 \\ -28000 \end{pmatrix}$	(± 6500)	(10.5-22)	$\begin{pmatrix} +1.6 \\ -1.6 \end{pmatrix}$	$\begin{pmatrix} +5.5 \\ -5.5 \end{pmatrix}$	(± 3000)	$\begin{pmatrix} +0.1 \\ -0.1 \end{pmatrix}$	$\begin{pmatrix} -.1 \\ -.28 \end{pmatrix}$
	b	± 600	± 4000	± 6000	± 3.2	± 0.5	± 3.8	± 600	± 0.045	± 0.04

*(a) Peak to Peak Variations Over the Orbit
(b) Maximum Spread Between Curves

(ODP SOLUTION PROPAGATED 1 ORBIT - CURRENT SOLUTION) VS. TIME
APOLLO 8

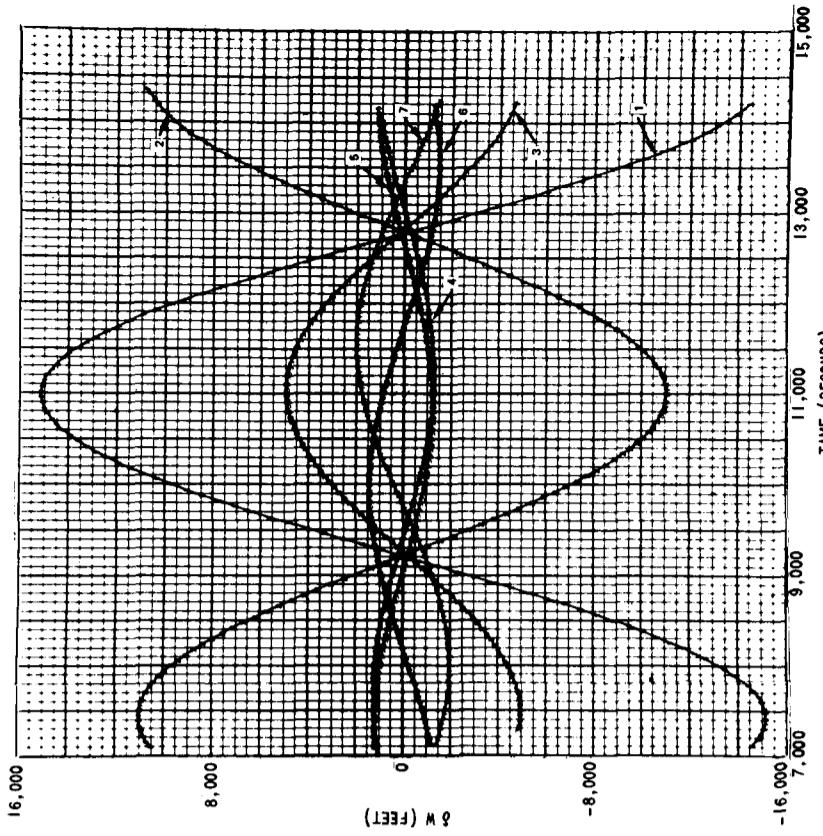
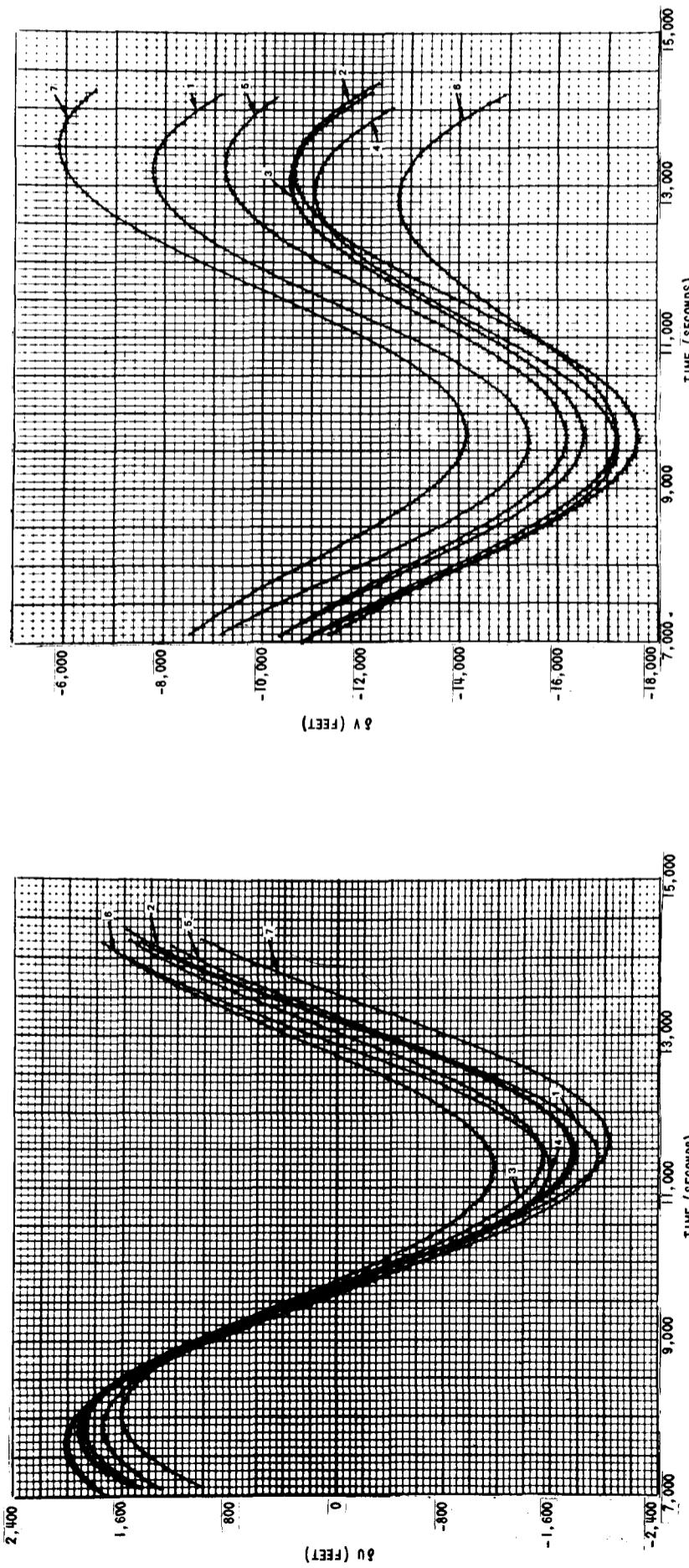


FIGURE 1

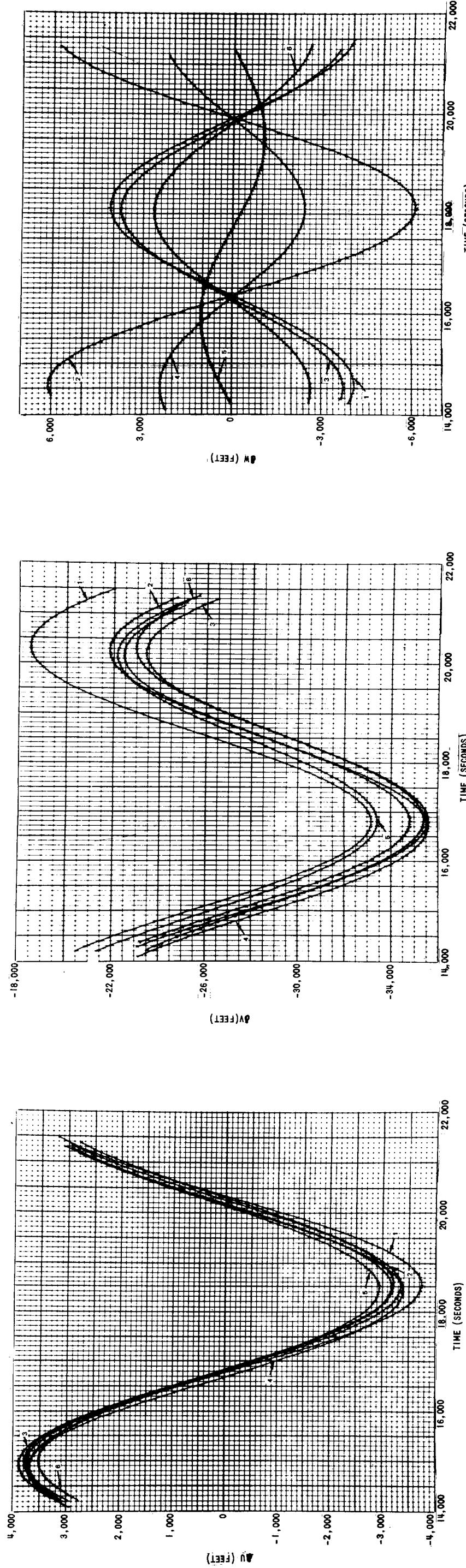
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B

FOLDOUT FRAME
A

HOLDOUT FRAME
B

HOLDOUT FRAME
A

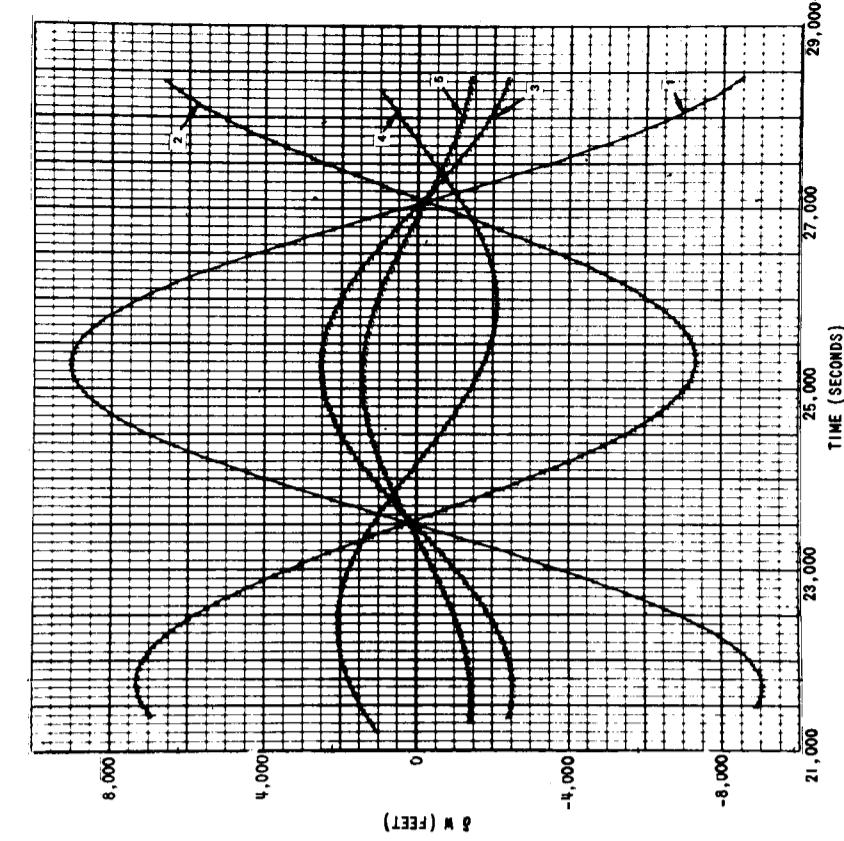
FIGURE 2



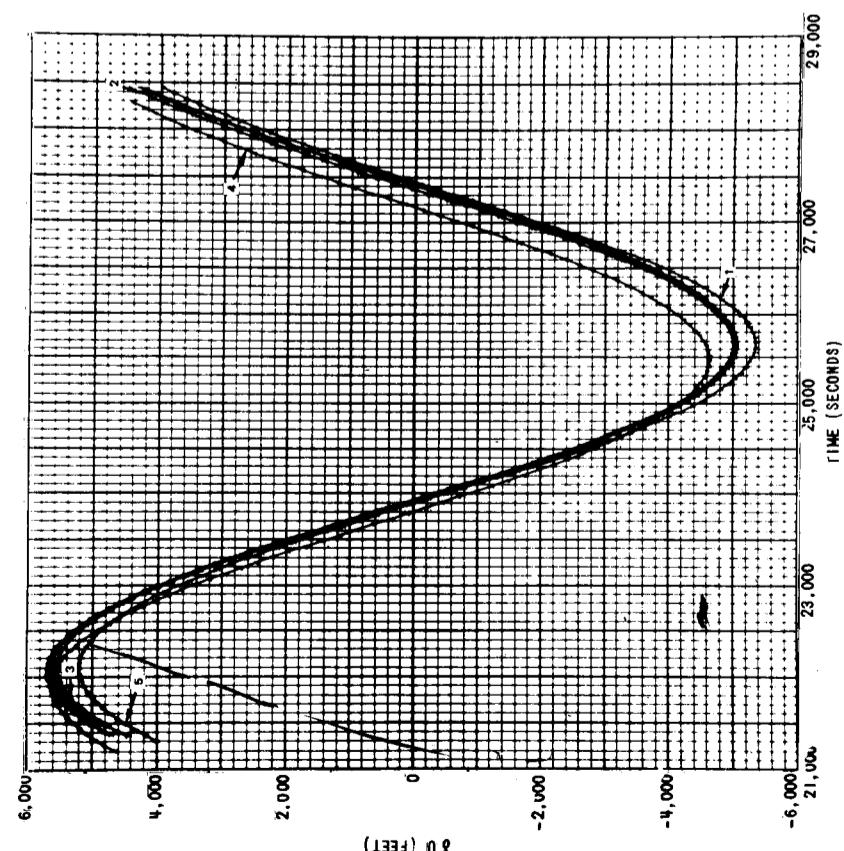
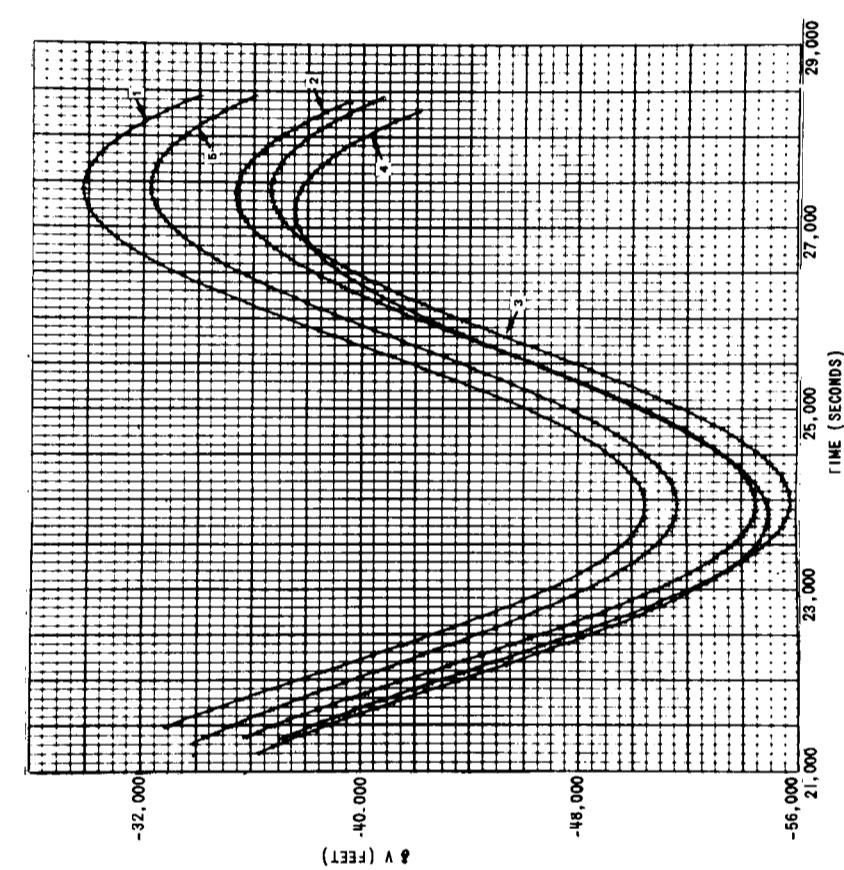
(DOP SOLUTION PROPAGATED 2 ORBITS - CURRENT SOLUTION) VS. TIME
APOLLO 8

FOLDOUT FRAME
B

FIGURE 3



(DDP SOLUTION PROPAGATED 3 ORBITS — CURRENT SOLUTION) VS. TIME
APOLLO 8



FOLDOUT FRAME
A

(ODP SOLUTION PROPAGATED / ORBIT - CURRENT SOLUTION) VS. TIME

APOLLO 8

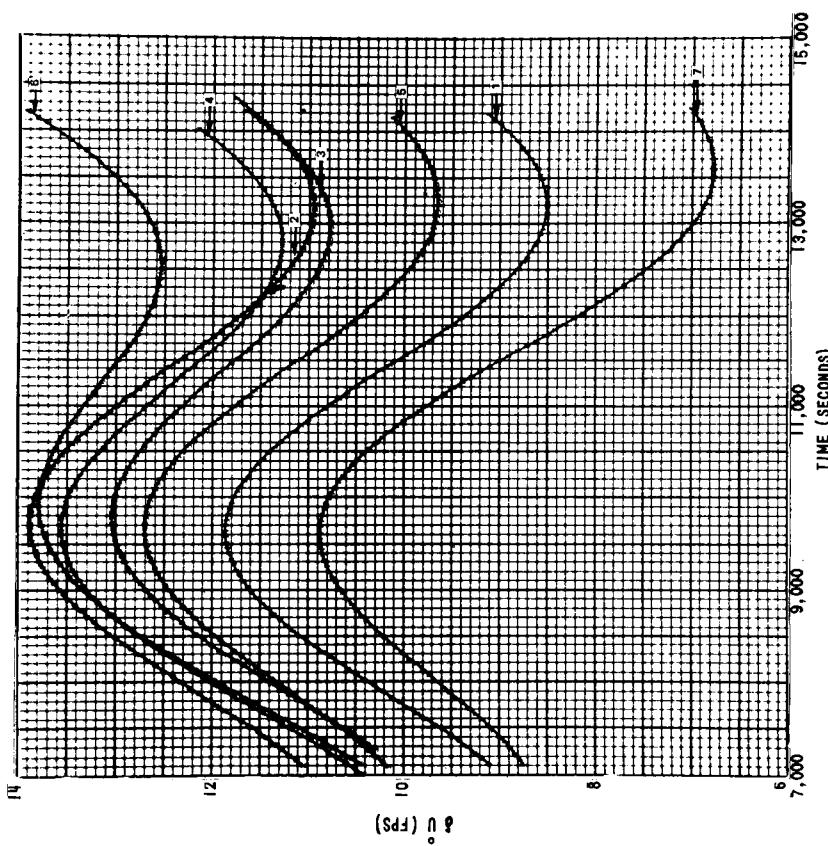
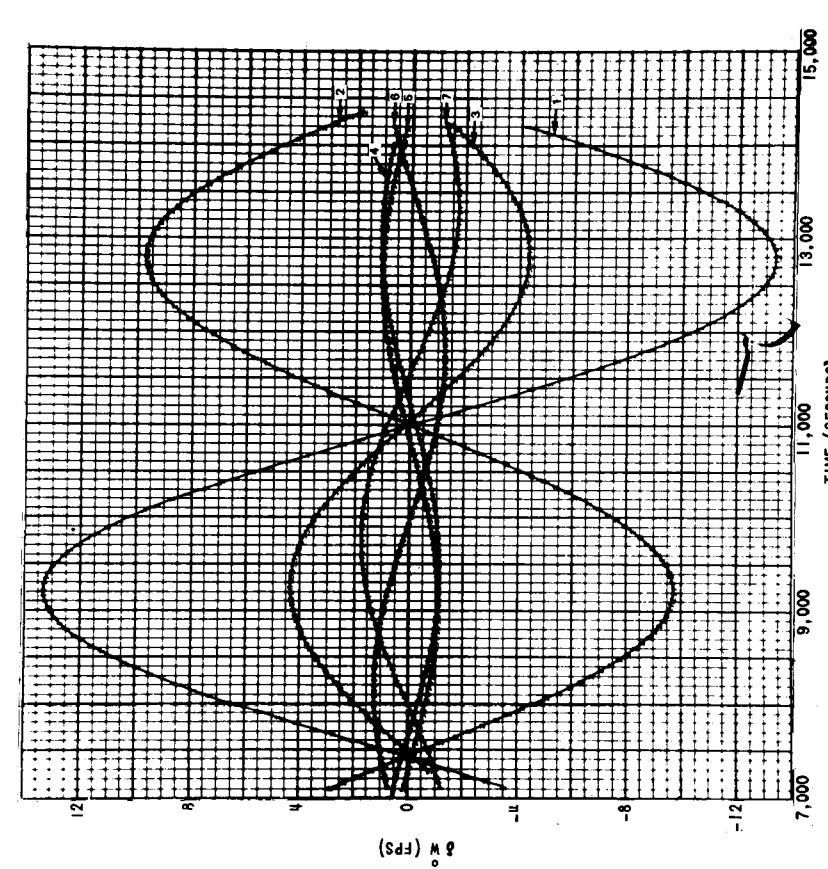
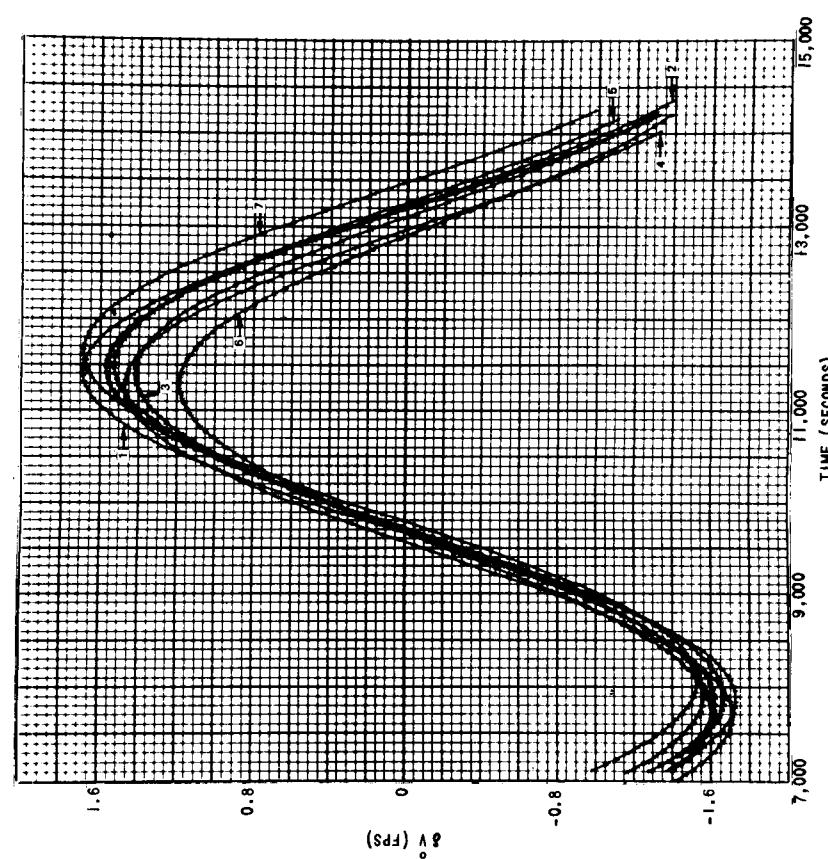


FIGURE 4



(00P SOLUTION PROPAGATED 2 ORBITS ← CURRENT SOLUTION) VS. TIME

APOLLO 8

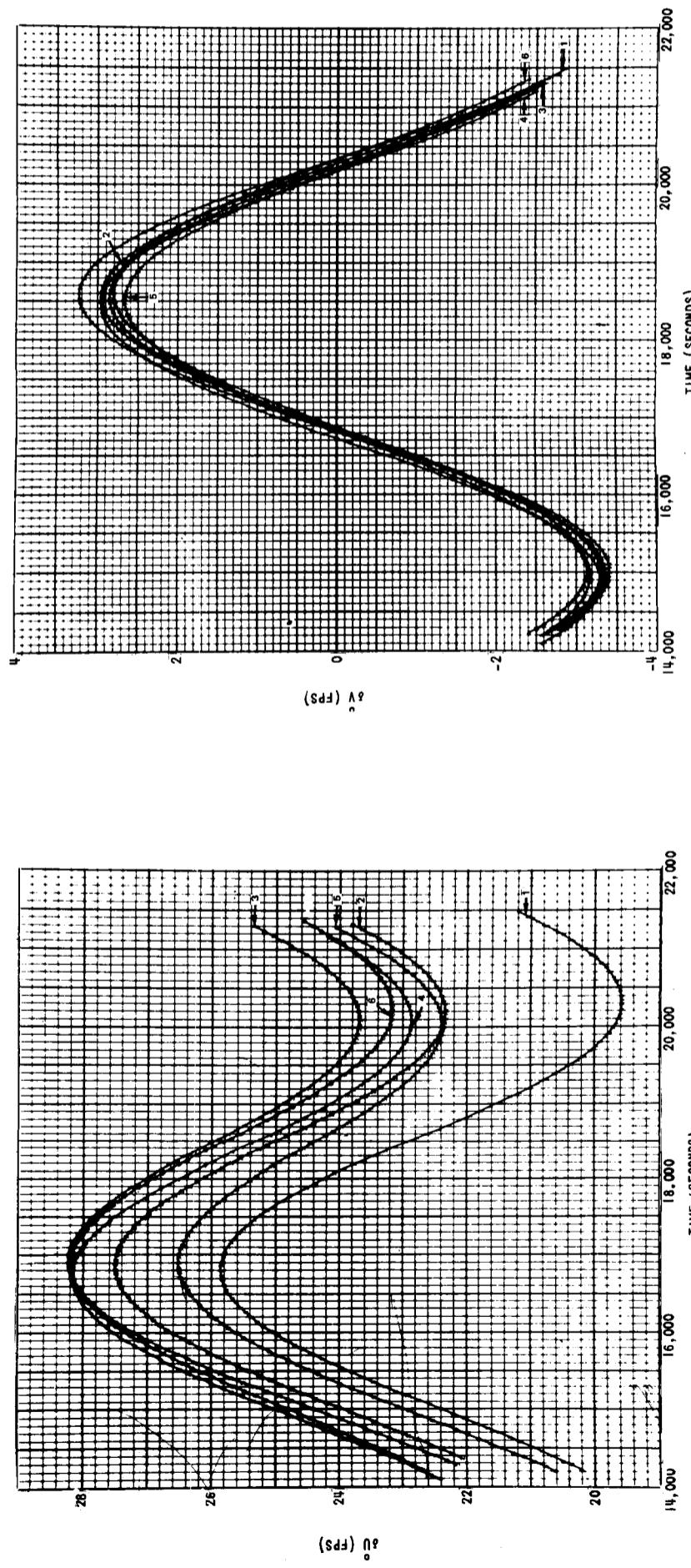
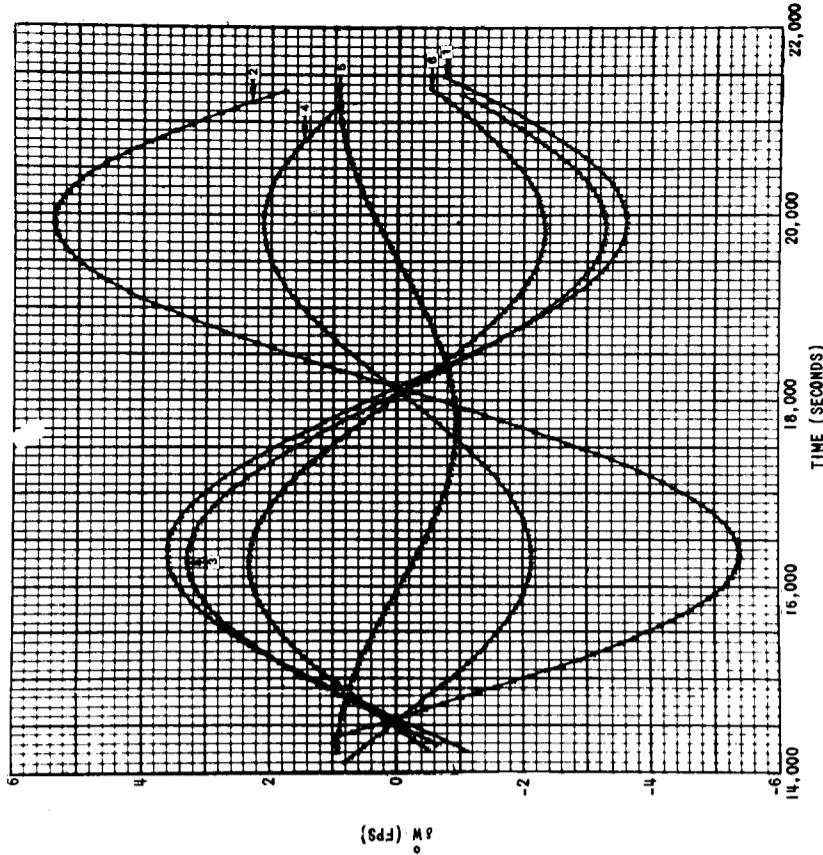


FIGURE 5

WINDOUT FRAME

A.



WINDOUT FRAME

B.

FOLDOUT FRAME
B.

TIME (SECONDS)

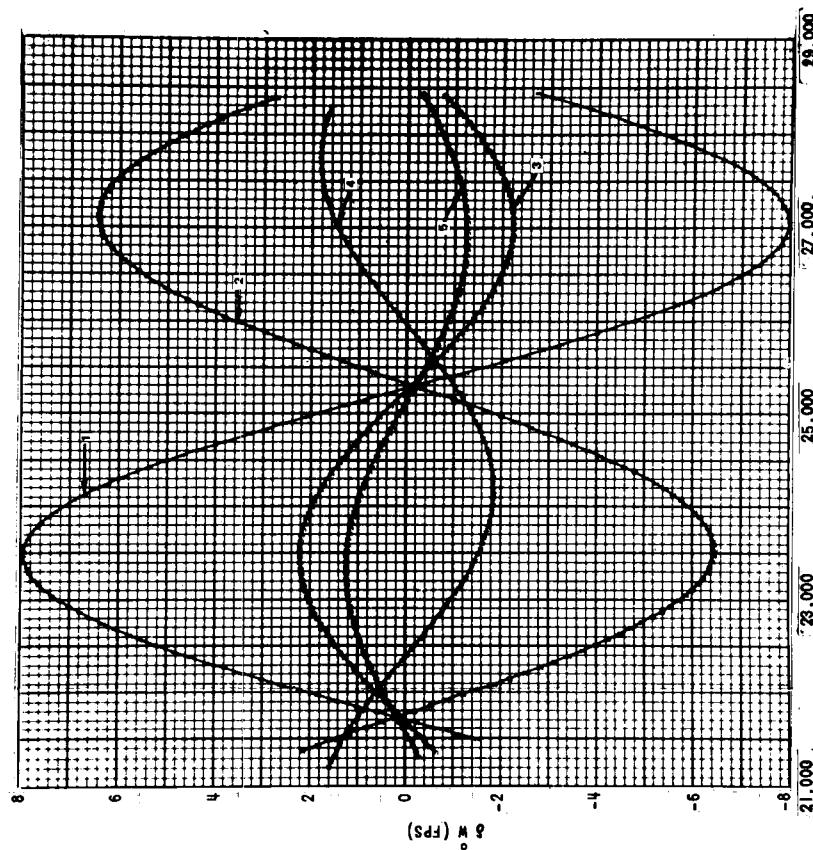
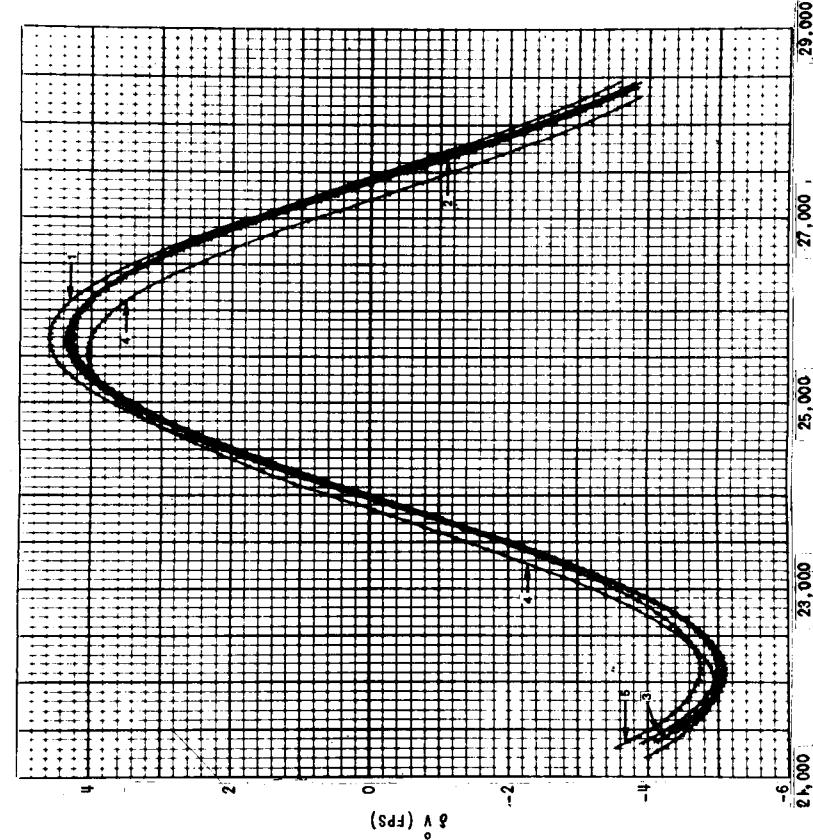
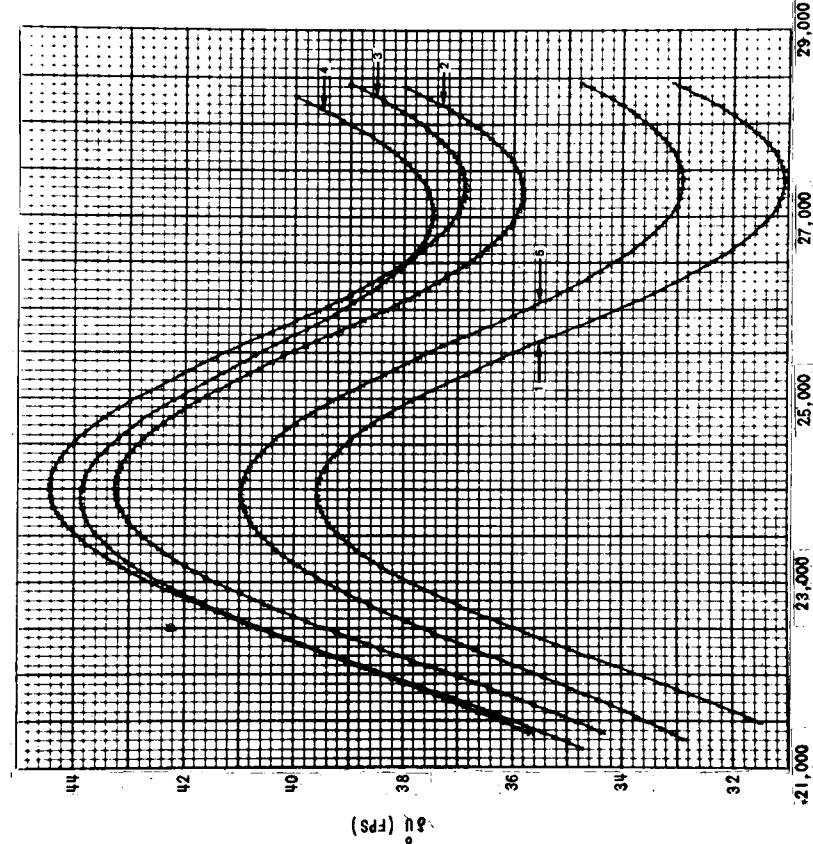


FIGURE 6

TIME (SECONDS)



TIME (SECONDS)



FOLDOUT FRAME
C.

(ODP SOLUTION PROPAGATED 3 ORBITS - CURRENT SOLUTION) VS. TIME

APOLLO 8

FOLDOUT FRAME
B

FOLDOUT FRAME
A

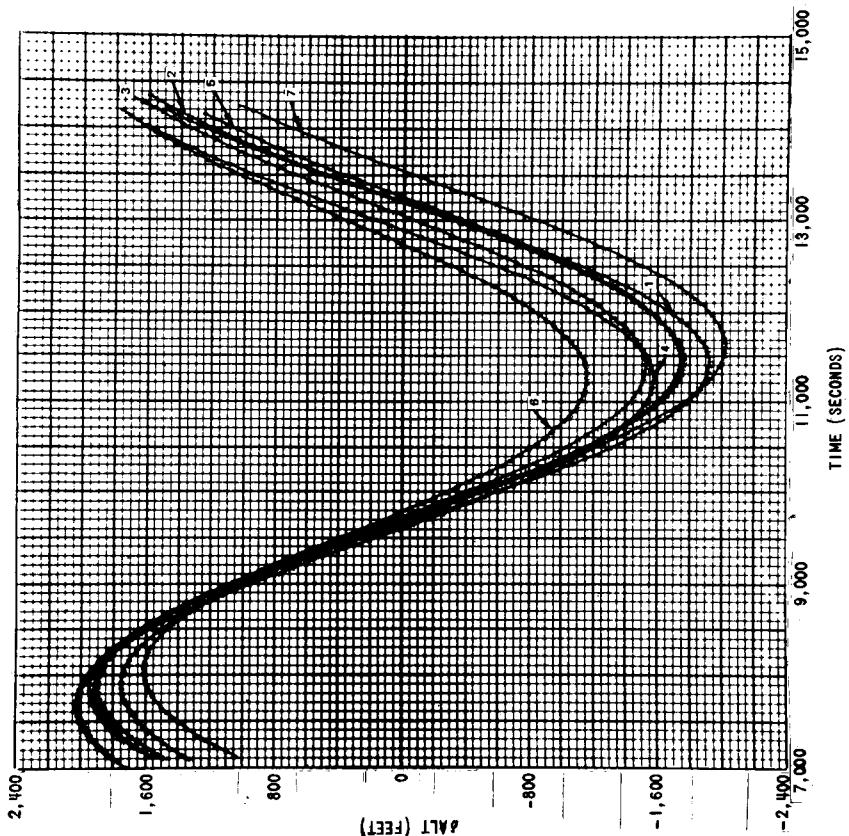
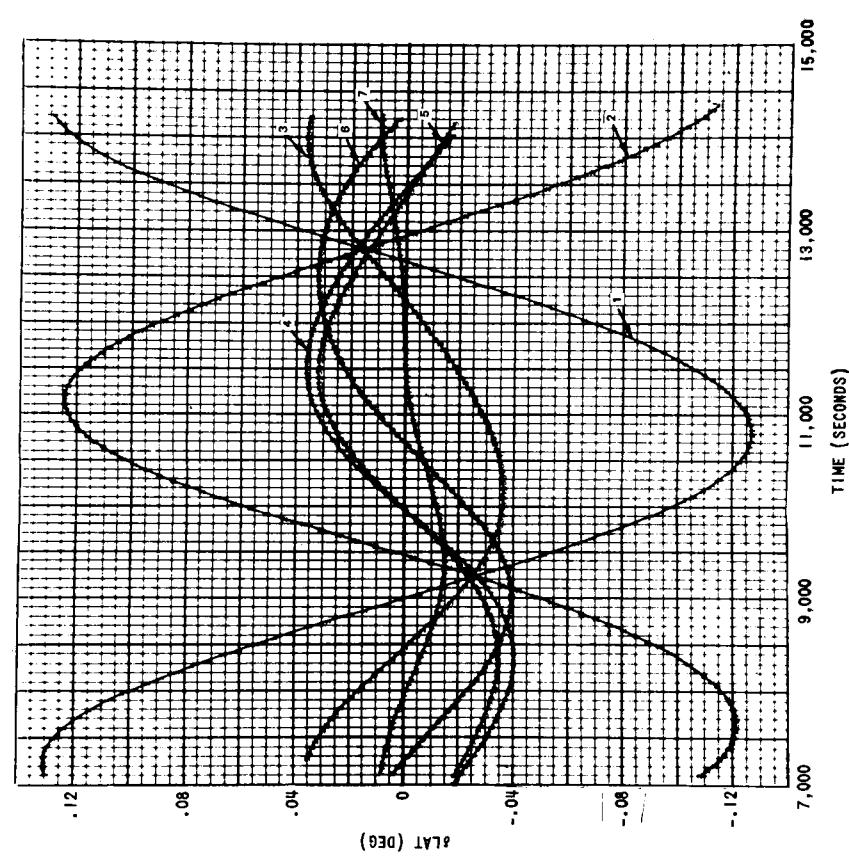
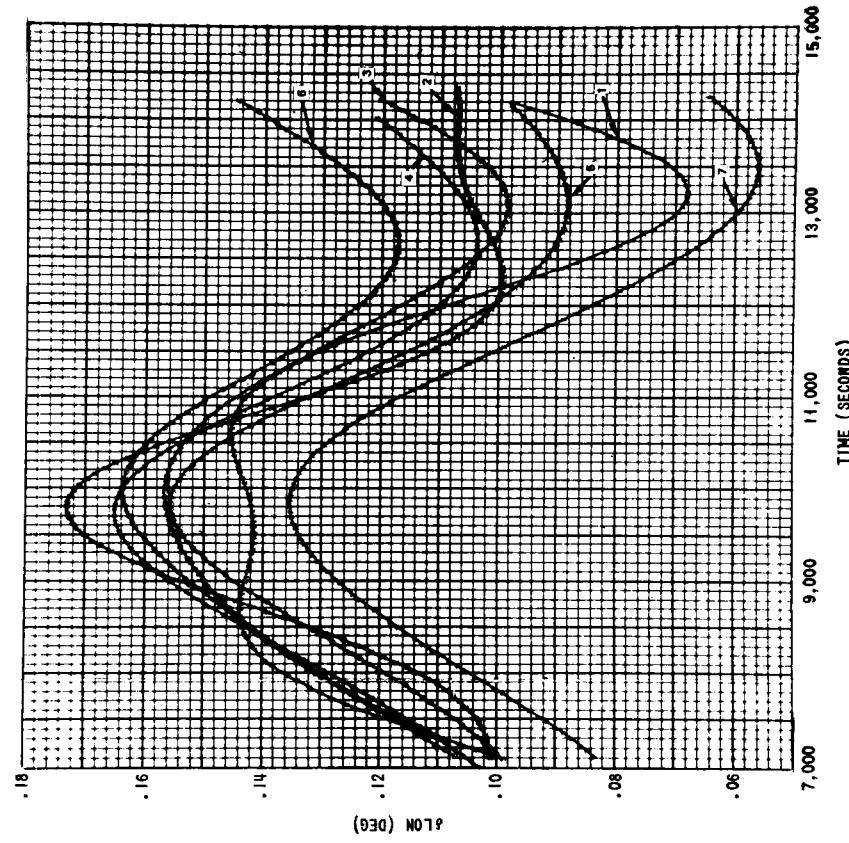


FIGURE 7

FOLDOUT FRAME
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(ODP SOLUTION PROPAGATED 2 ORBITS - CURRENT SOLUTION) VS. TIME
APOLLO 8

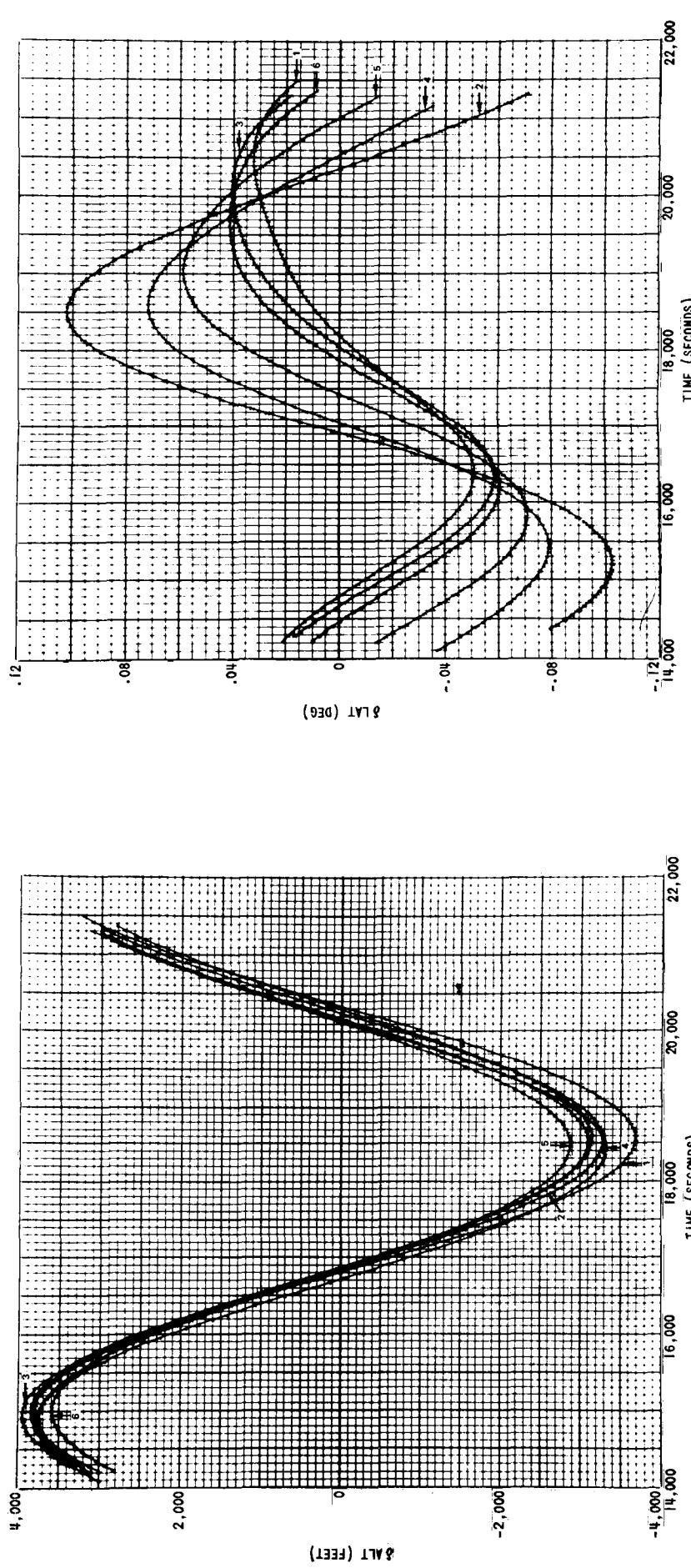
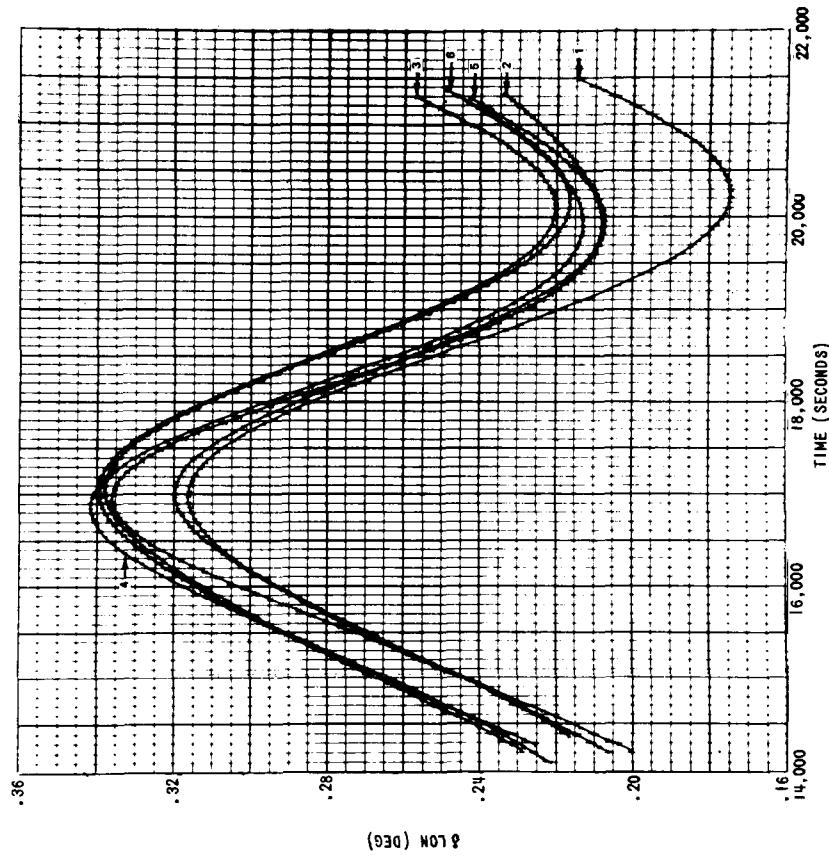


FIGURE 8



TIME (SECONDS)

ΔLAT (DEG)

FOLDOUT FRAME
A

(DDP SOLUTION PROPAGATED 3 ORBITS - CURRENT SOLUTION) VS. TIME

APOLLO 8

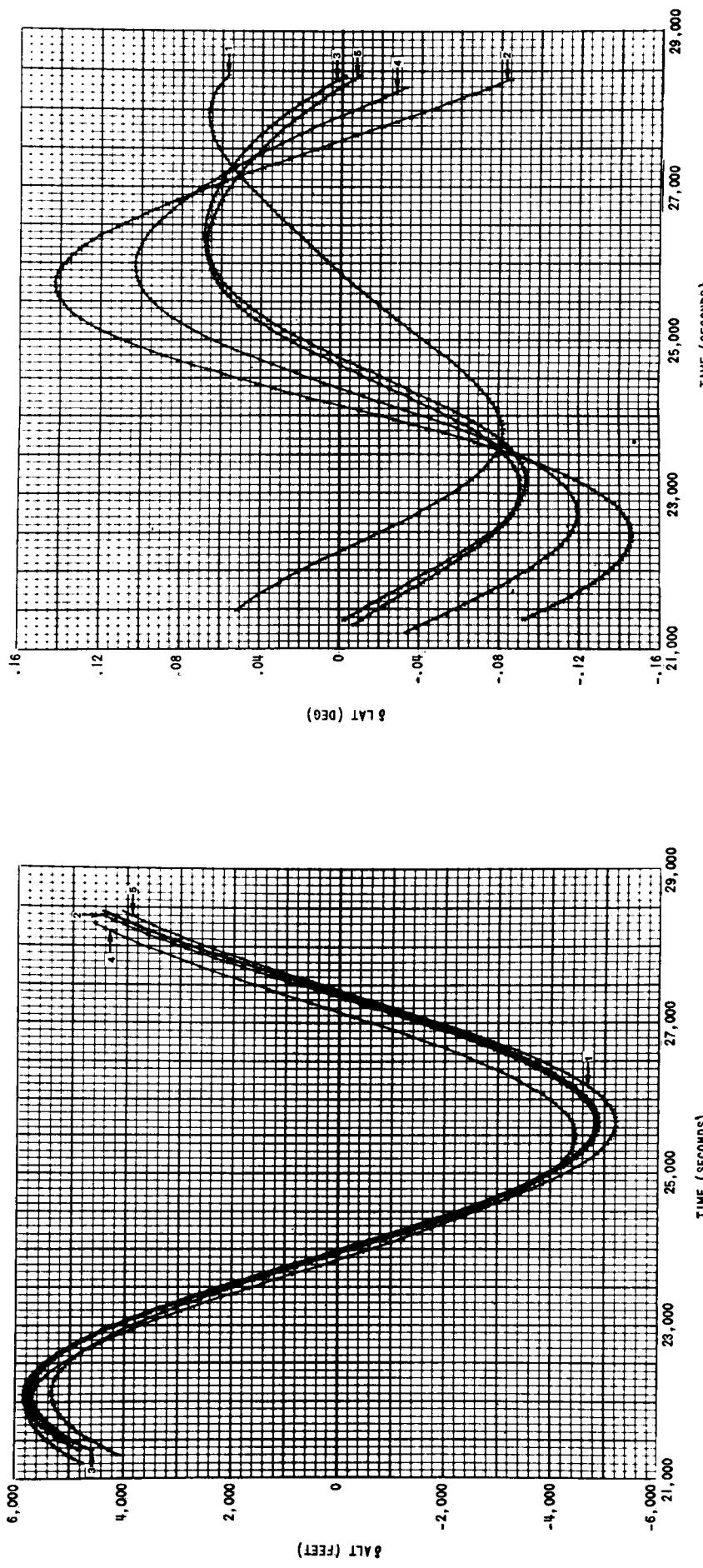
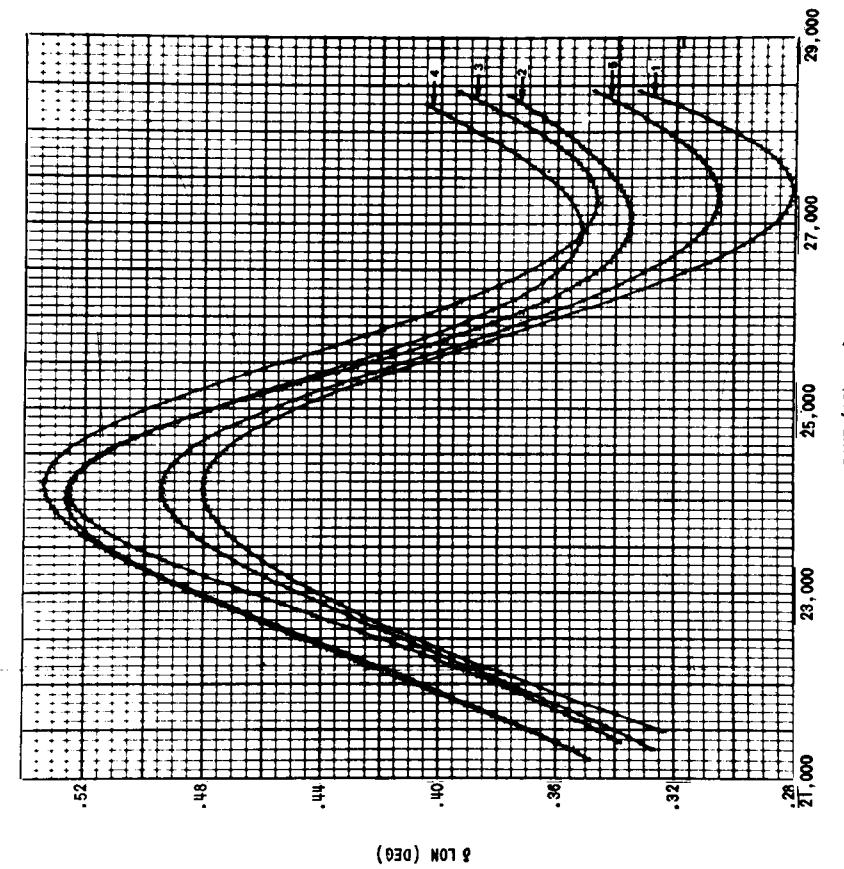


FIGURE 9

FOLDOUT FRAME
A-



TIME (SECONDS)

FOLDOUT FRAME
B-

COMPOSITE OF (ODP SOLUTIONS PROPAGATED - CURRENT SOLUTION) VS. TIME
APOLLO 8

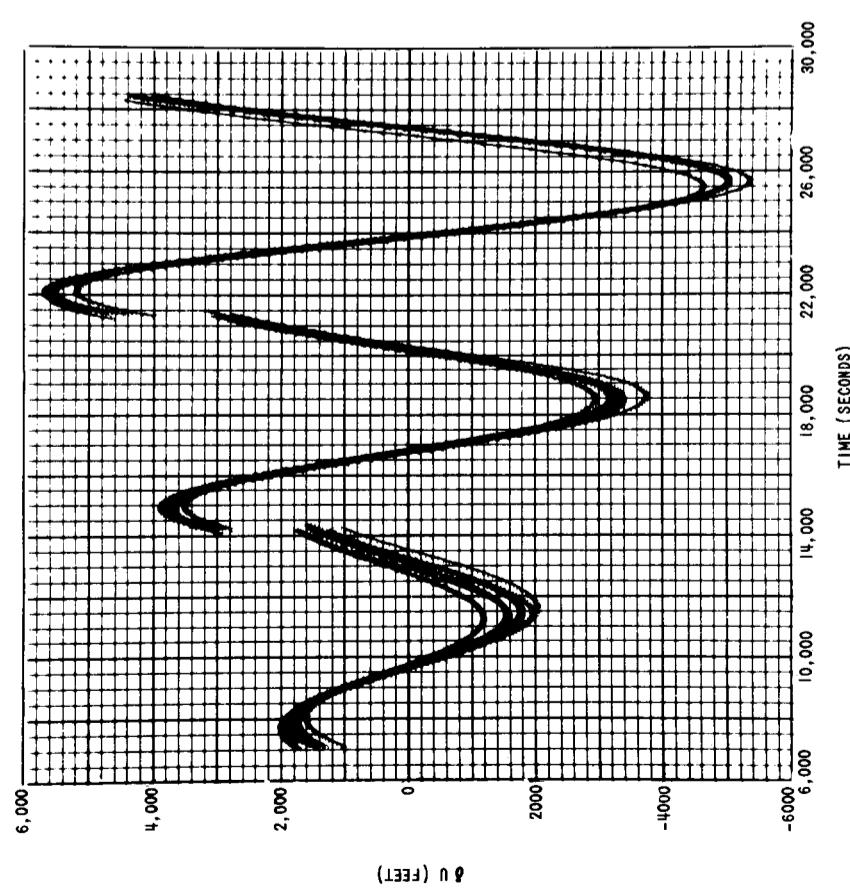


FIGURE 10

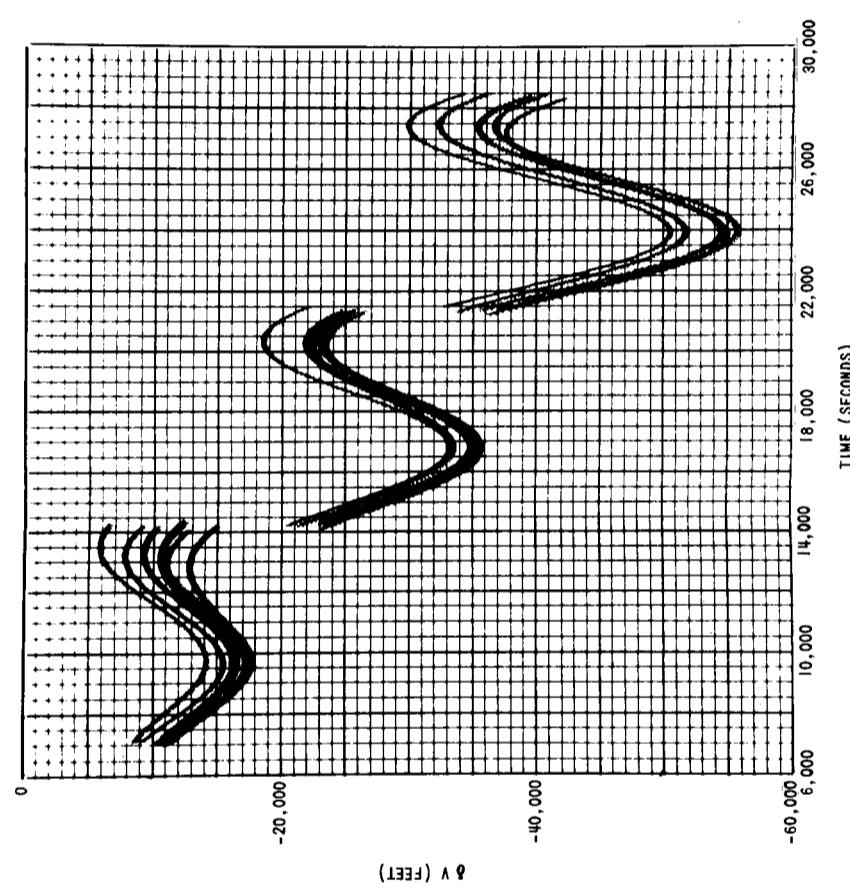


FIGURE 10

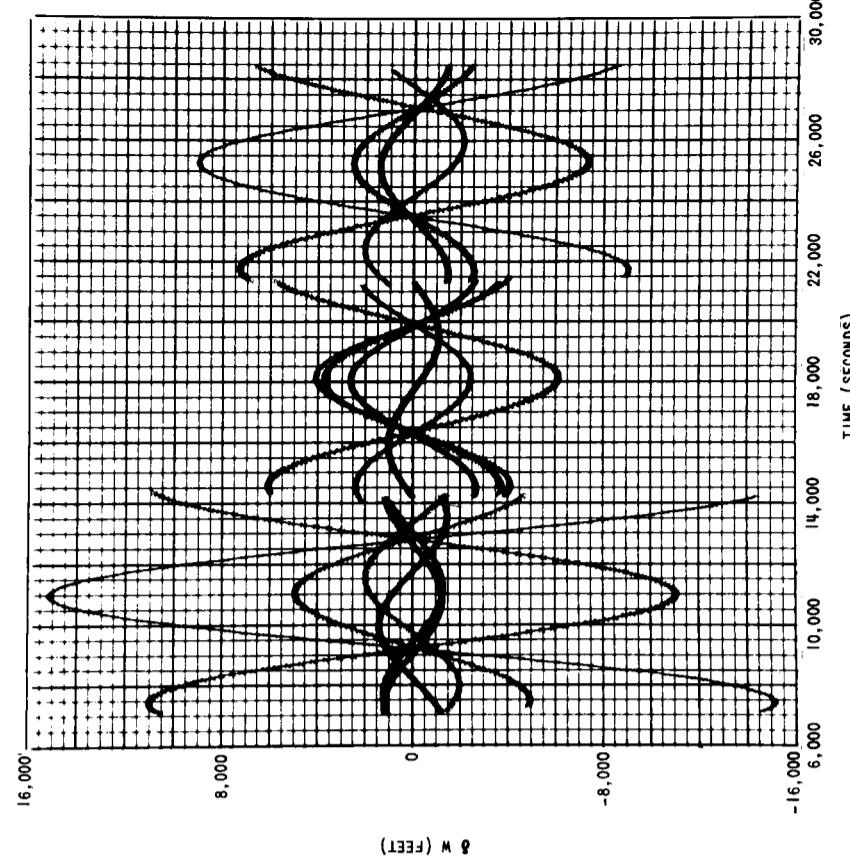


FIGURE 10

FOLDOUT FRAME
A

FOLDOUT FRAME
B

COMPOSITE OF (ODP SOLUTIONS PROPAGATED - CURRENT SOLUTION) VS. TIME
APOLLO 8

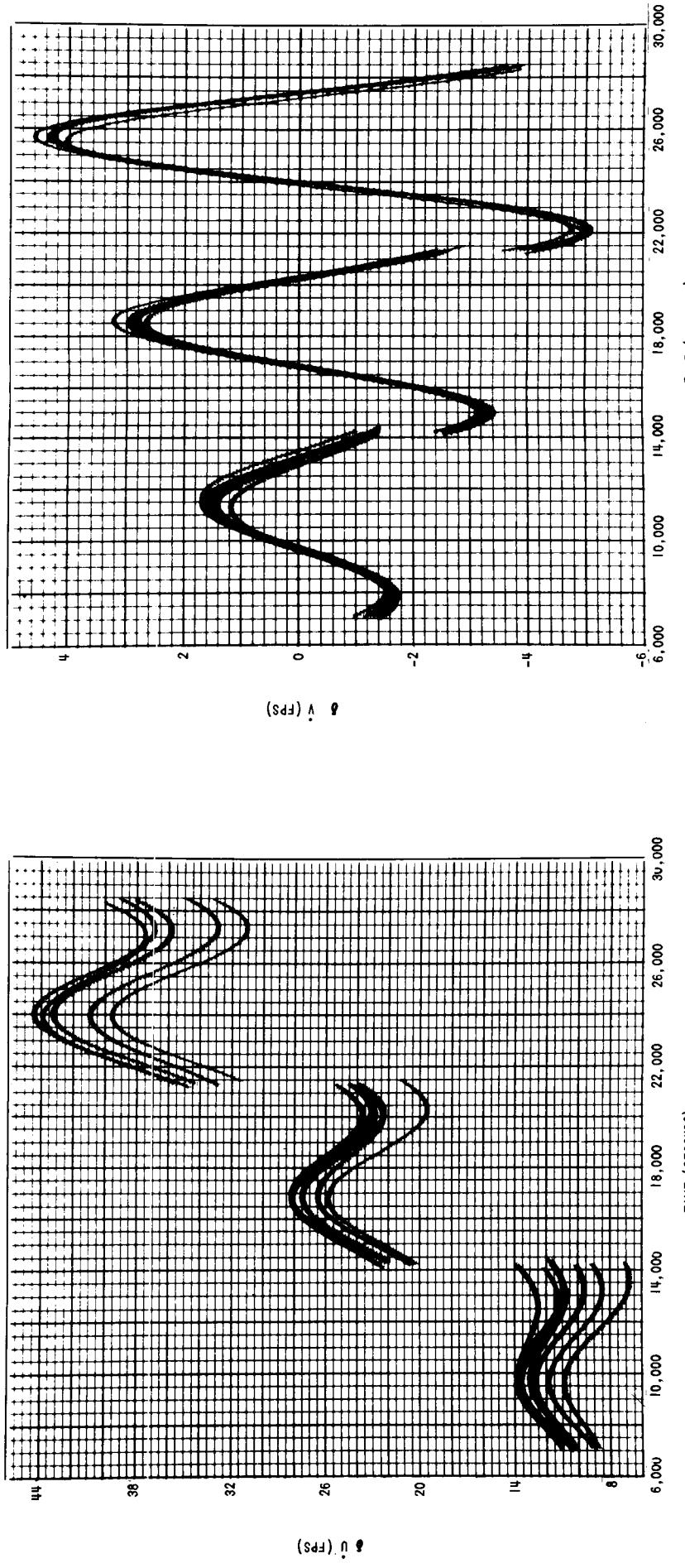
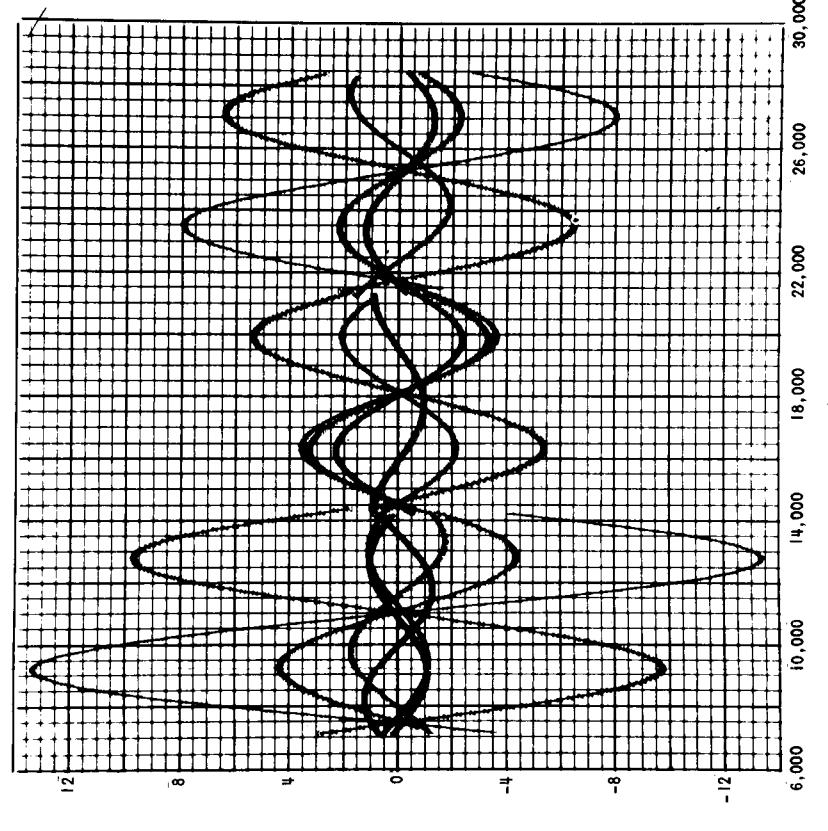


FIGURE 11



TIME (SECONDS)

POLDOUT FRAME
ff

POLDOUT FRAME
B

COMPOSITE OF (ODP SOLUTIONS PROPAGATED - CURRENT SOLUTION) VS. TIME
APOLLO 8

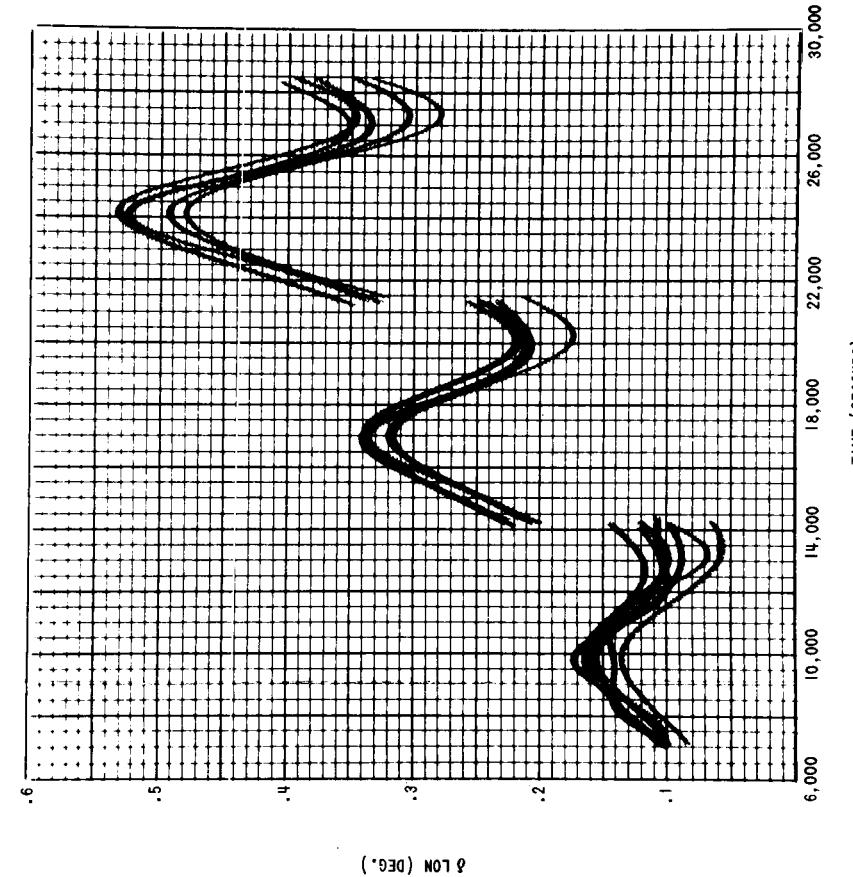
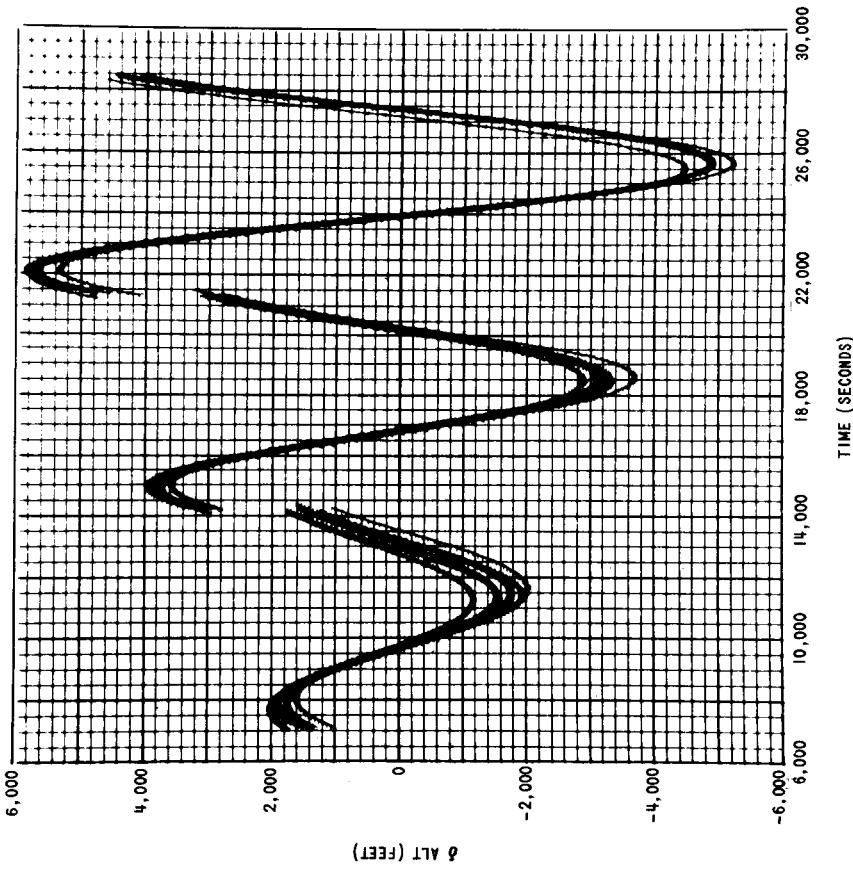


FIGURE 12

FOLDOUT FRAME A



FOLDOUT FRAME B

COMPOSITE OF (ODP SOLUTIONS PROPAGATED - CURRENT SOLUTION) VS. TIME

APOLLO 8

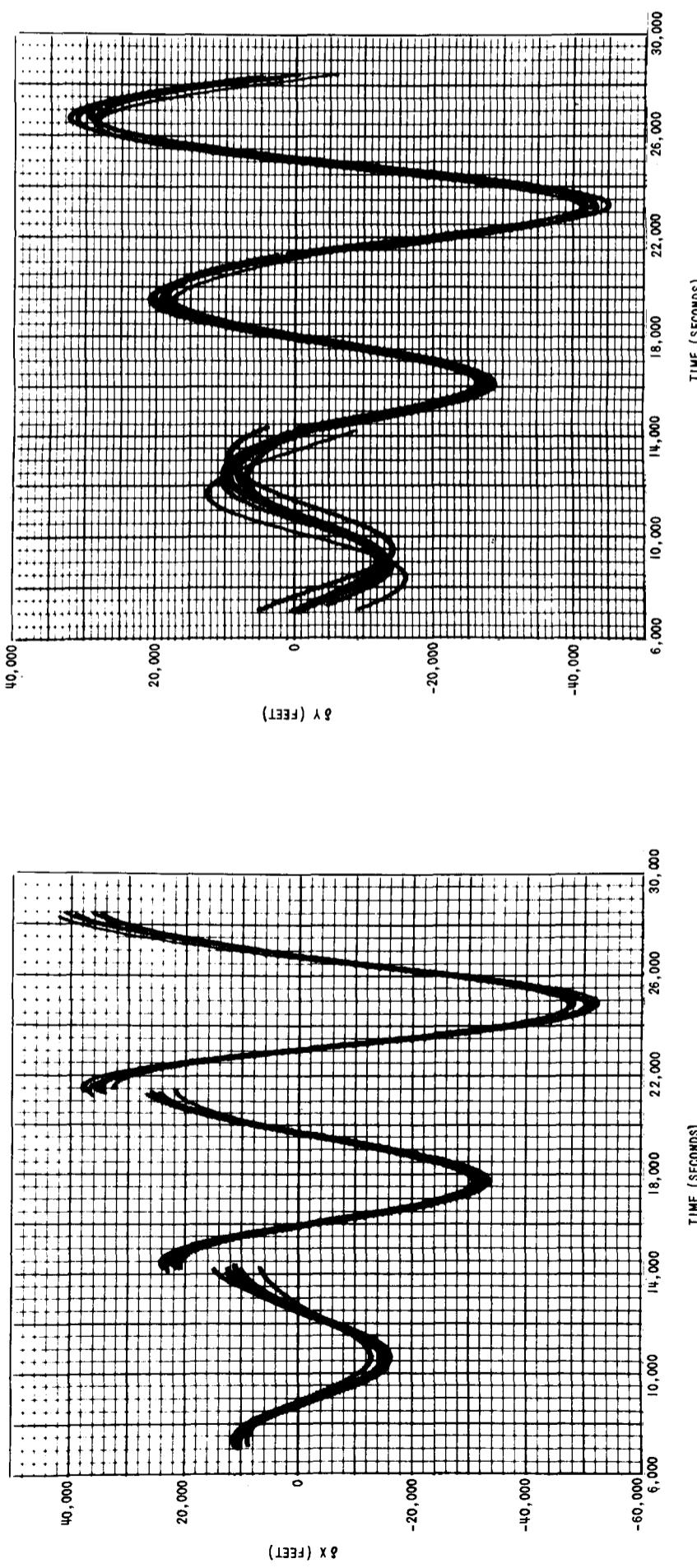


FIGURE 13

TIME (SECONDS)

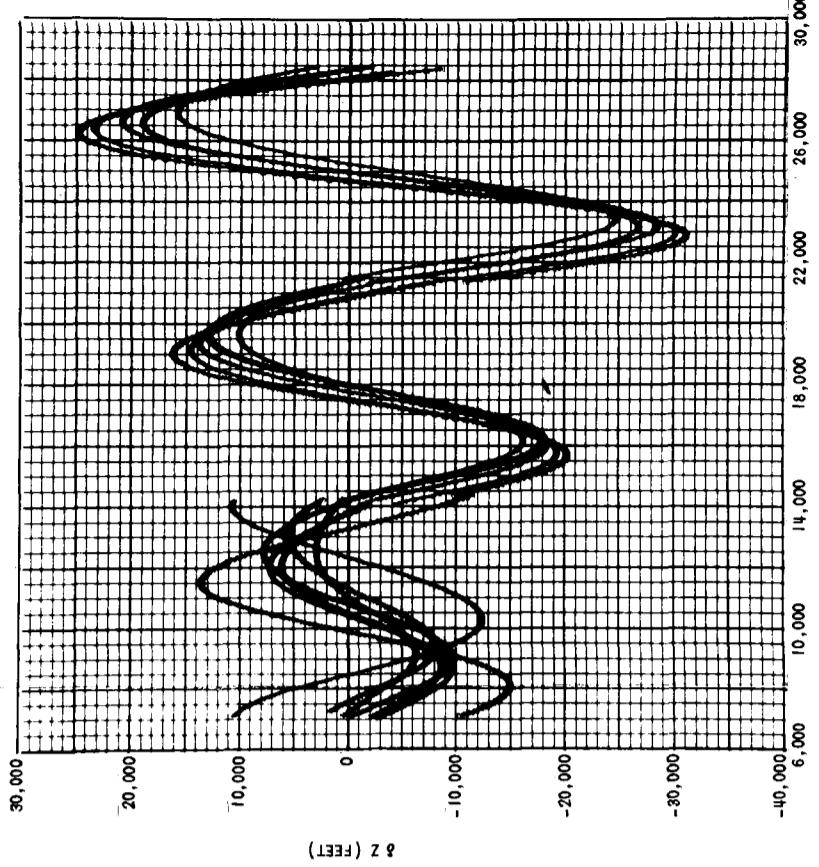


FIGURE 13

FOLDOUT FRAME
B

FOLDOUT FRAME
F

FOLDOUT FRAME
B

COMPOSITE OF (ODP SOLUTIONS PROPAGATED - CURRENT SOLUTION) VS. TIME

APOLLO 8

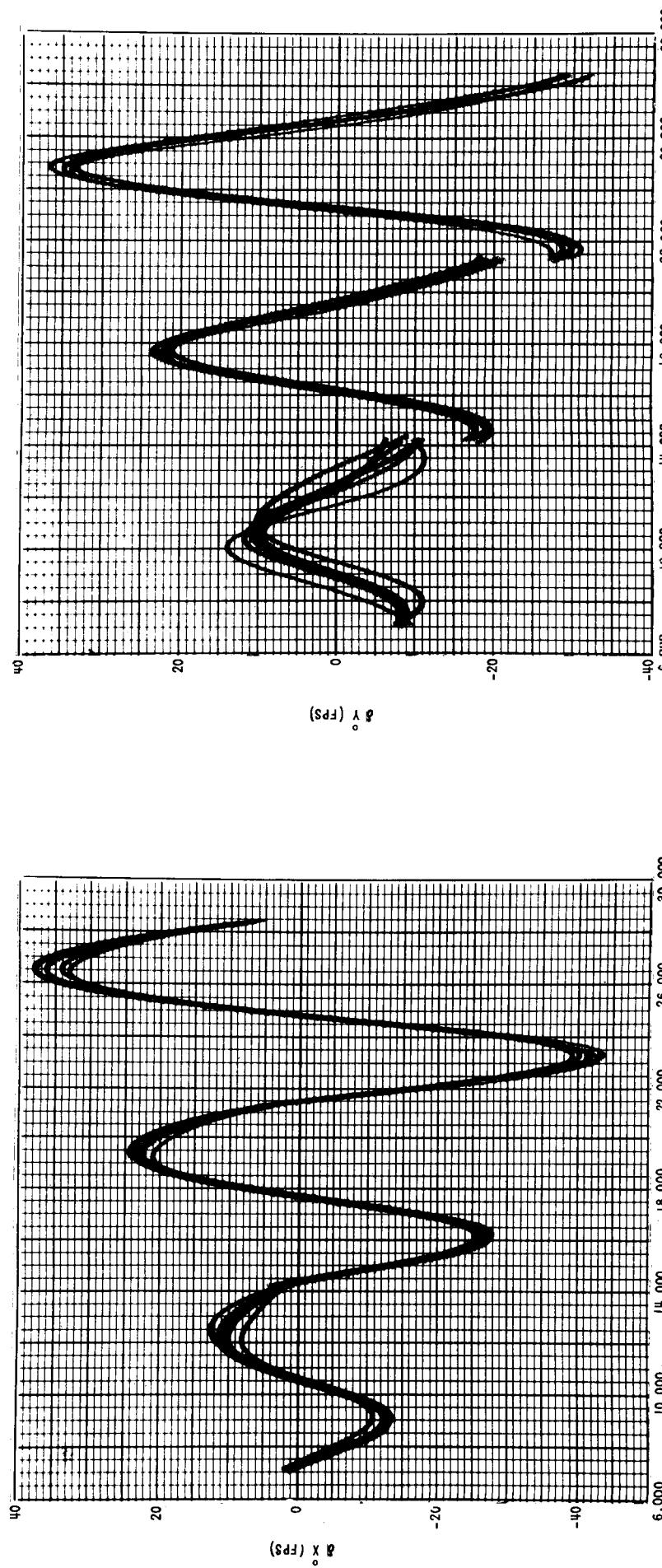


FIGURE 14

FOLDOUT FRAME
A

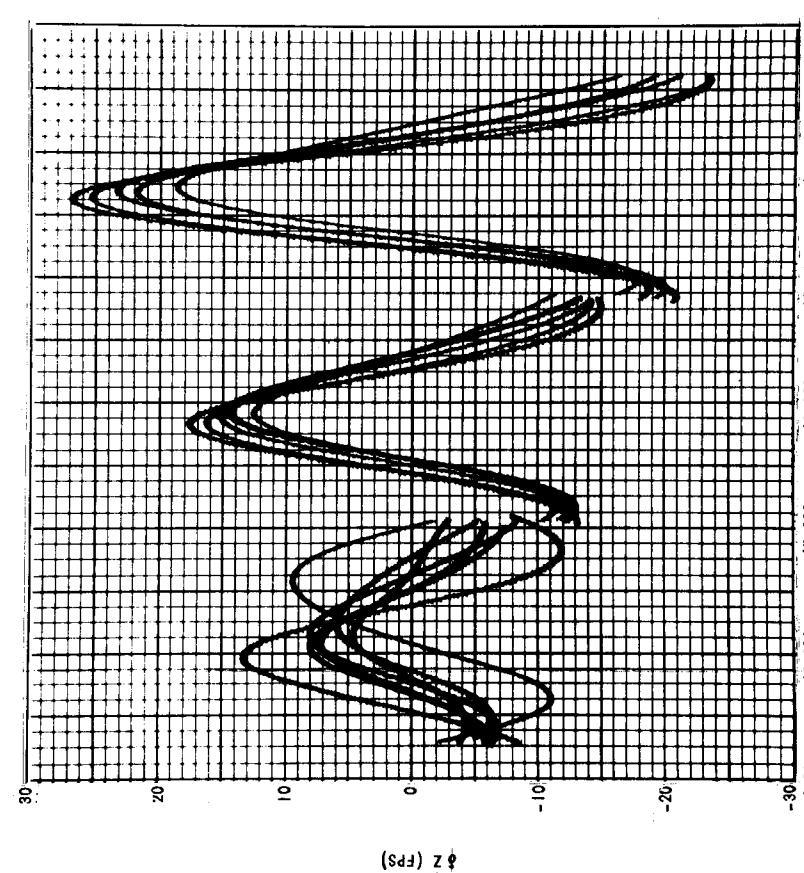
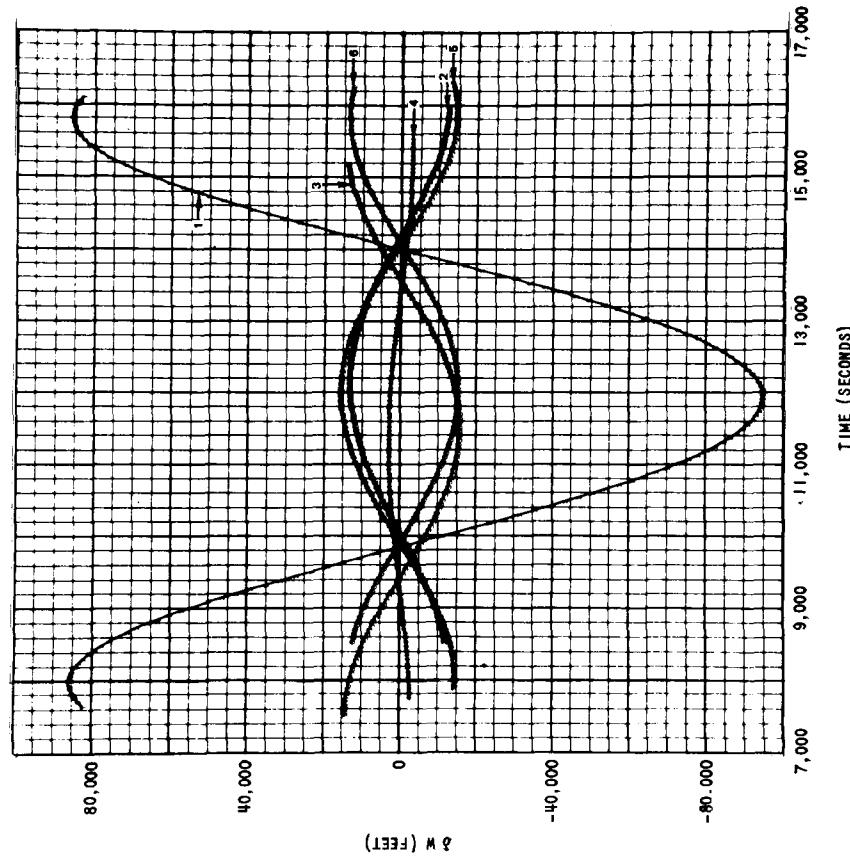


FIGURE 14

FOLDOUT FRAME
B.



TIME (SECONDS)

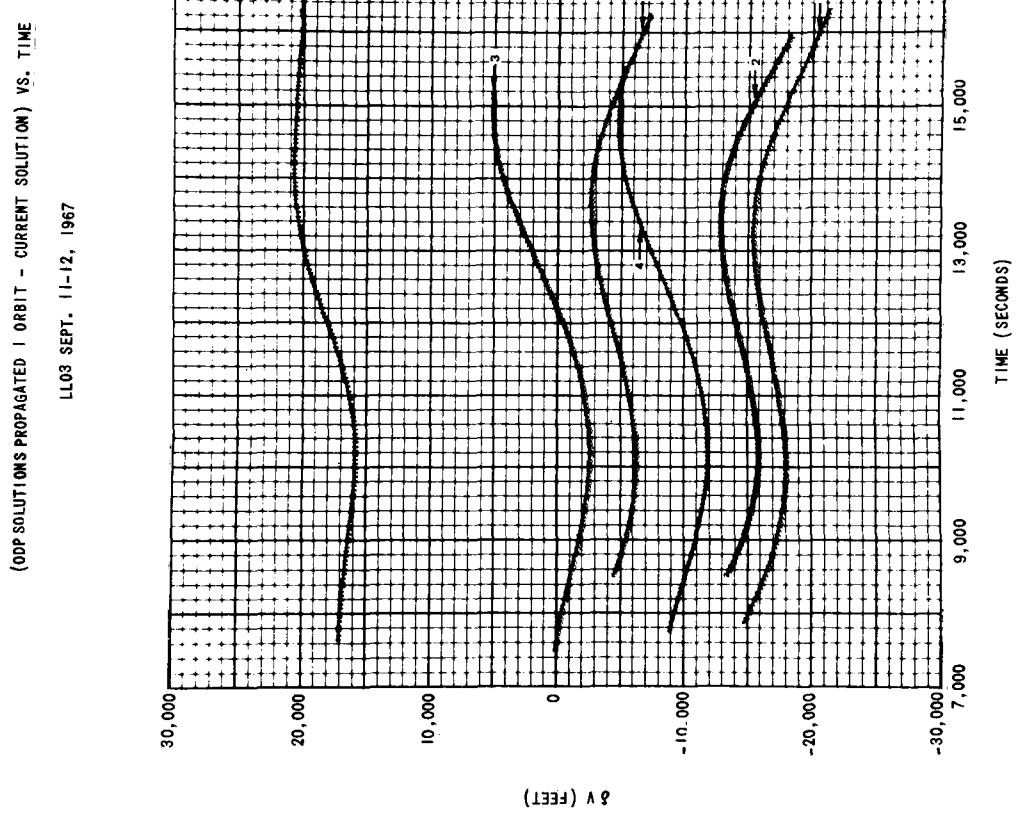
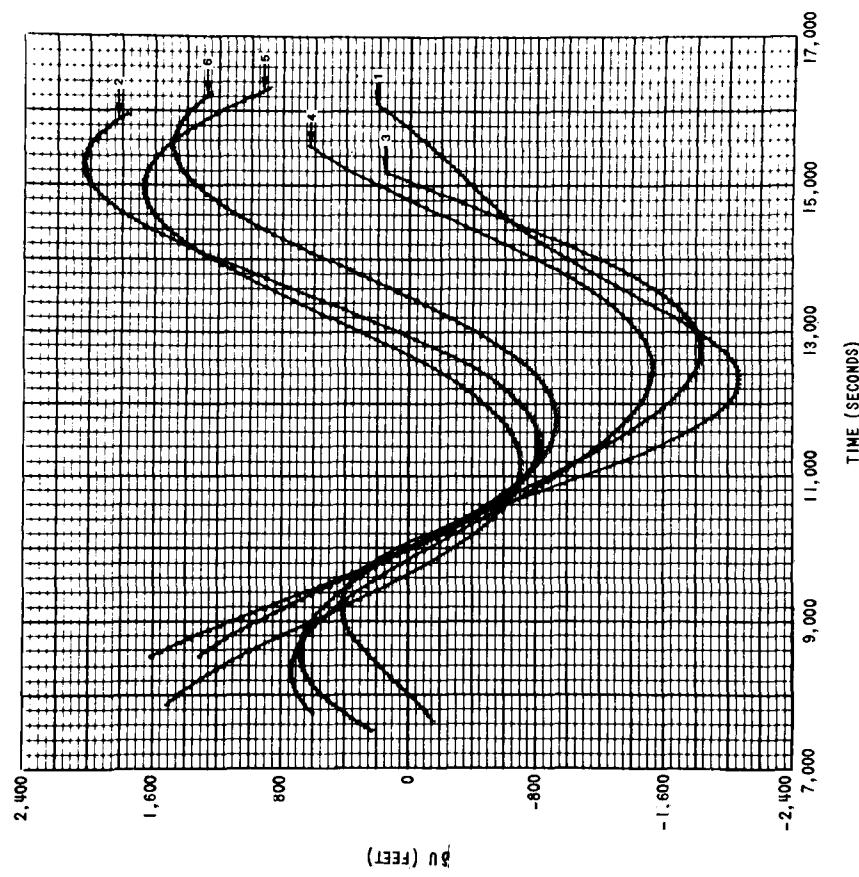


FIGURE 15



TIME (SECONDS)

FOLDOUT FRAME
A

(DOP SOLUTION PROPAGATED 2 ORBITS - CURRENT SOLUTION) V.S. TIME
LL03 SEPT. 11-12, 1967

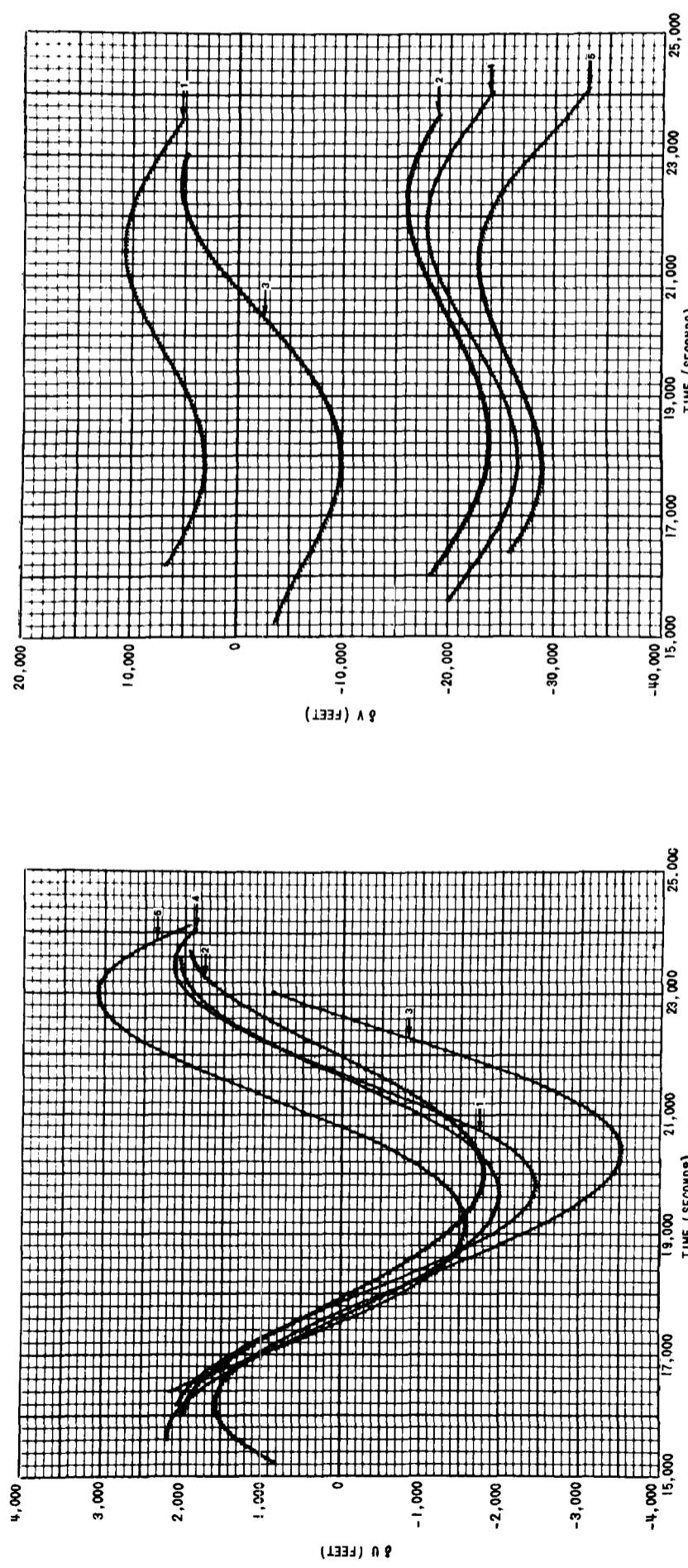


FIGURE 16

FOLLOWUP PREDICTION

FOLLOWUP PREDICTION

B.

(ODP SOLUTION PROPAGATED 3 ORBITS - CURRENT SOLUTION) VS. TIME
LL03 SEPT. 11-12, 1967

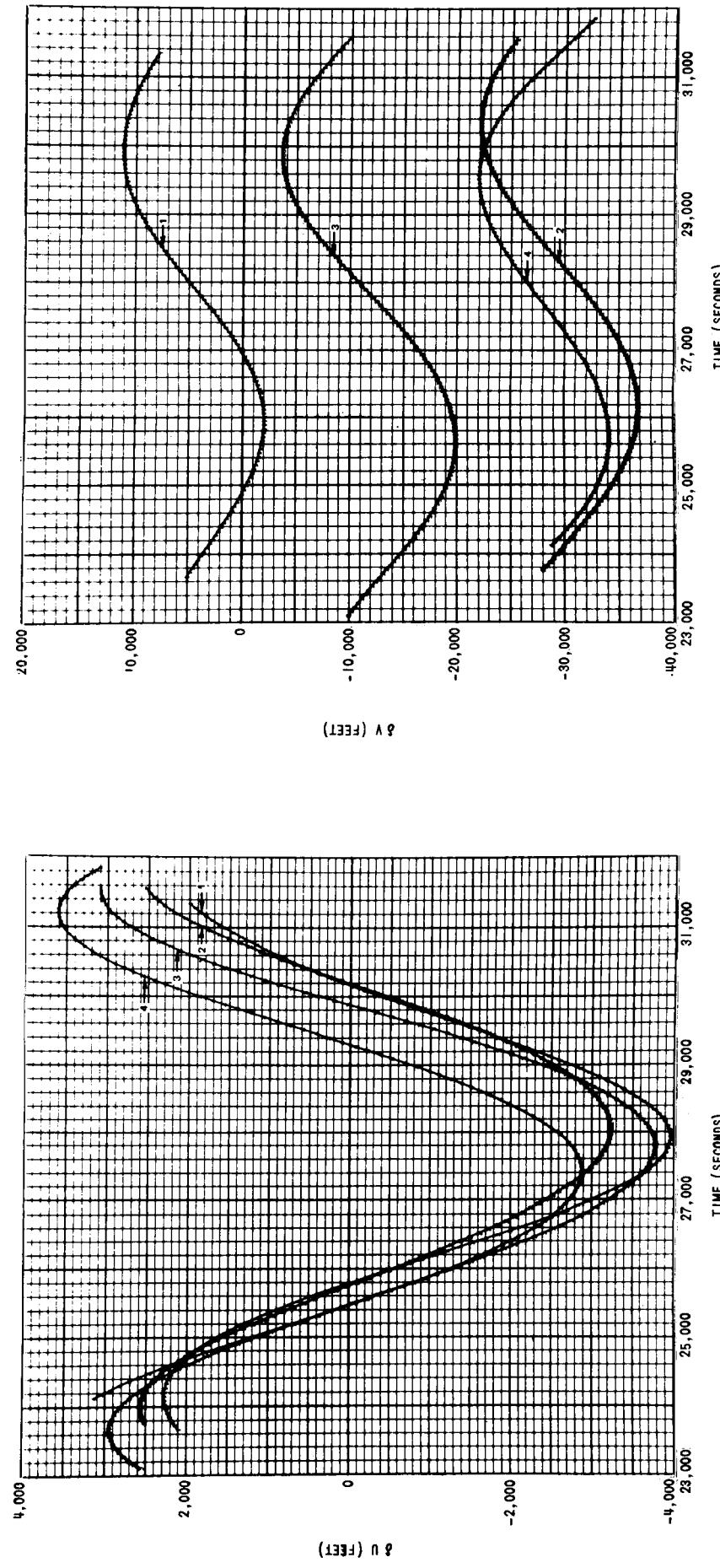
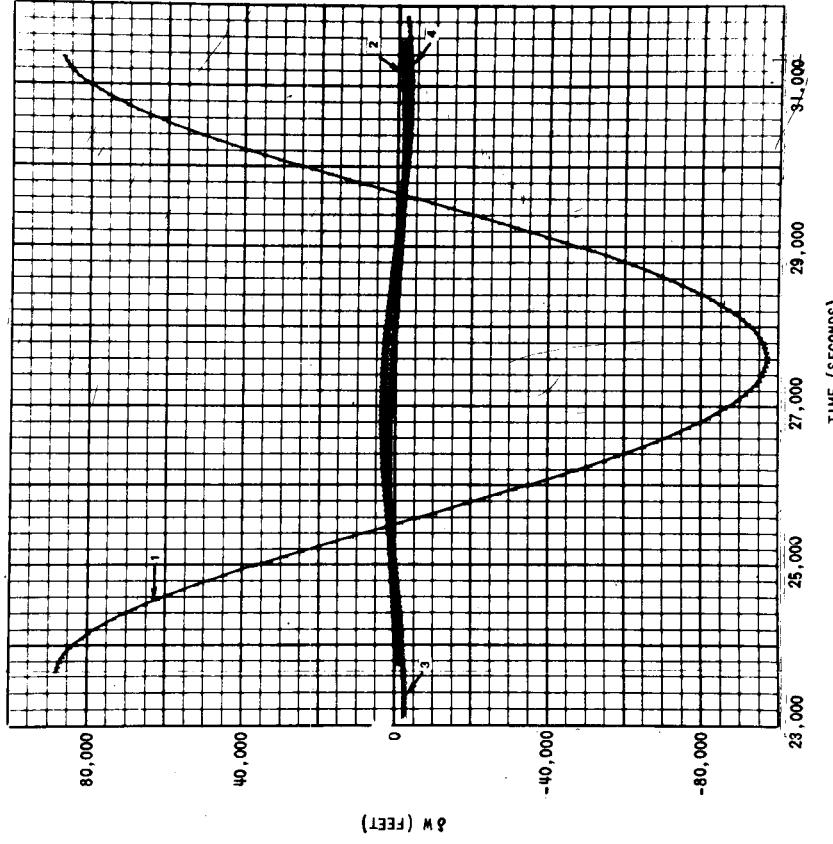


FIGURE 17



TIME (SECONDS)

 δW (FEET)

(ODP SOLUTION PROPAGATED 1 ORBIT - CURRENT SOLUTION) VS. TIME

LL03 SEPT. 11-12, 1967

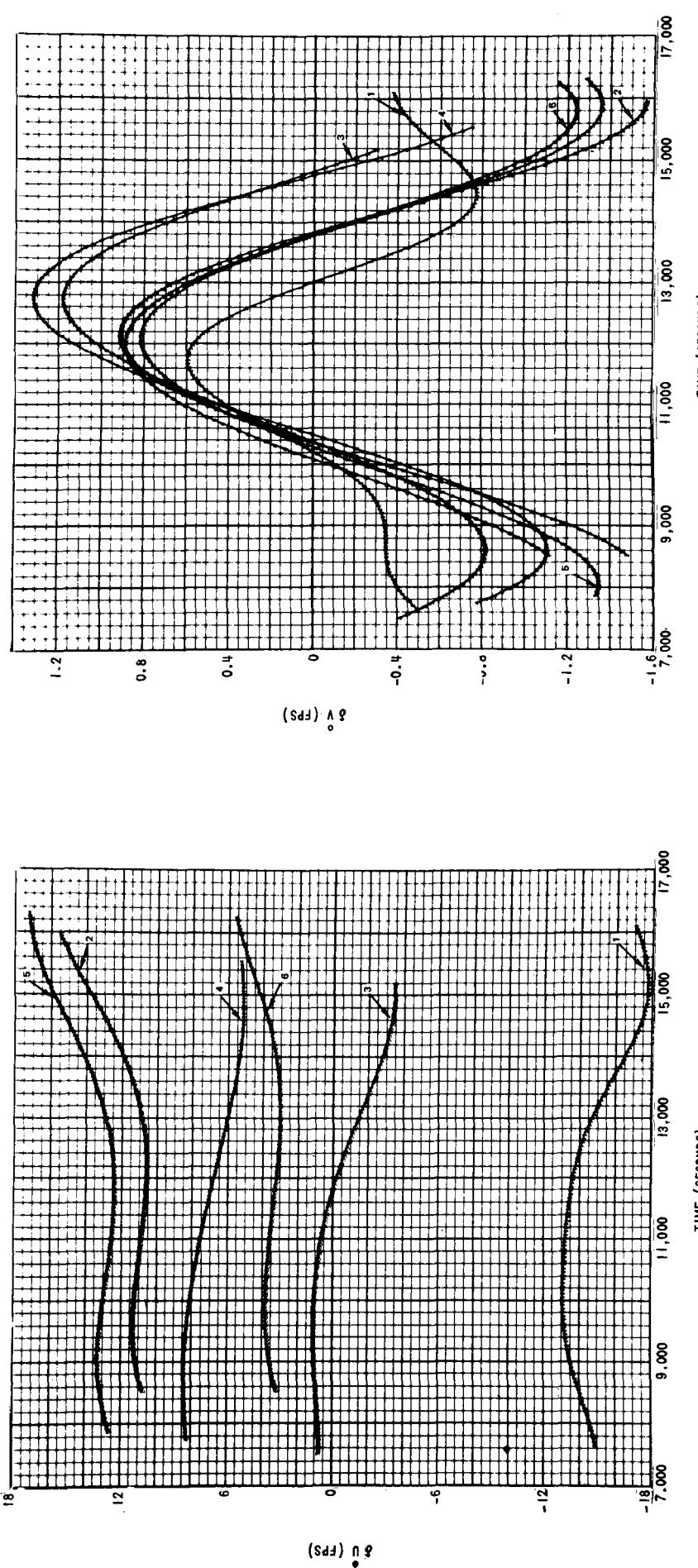


FIGURE 18

FOLDOUT FRAME
H

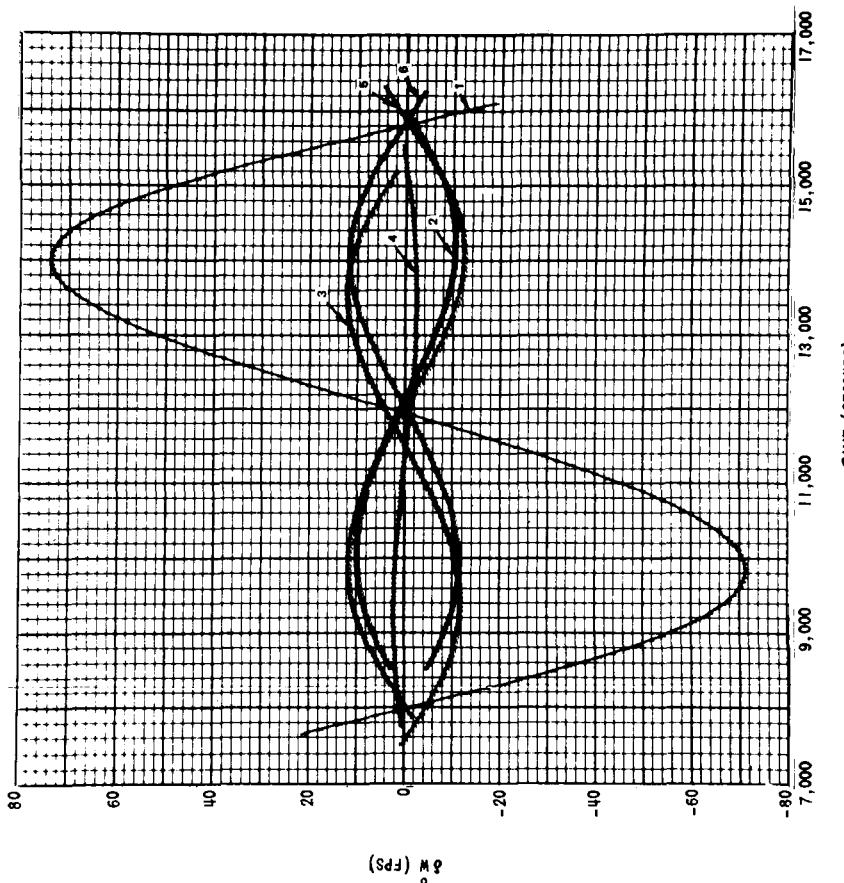


FIGURE 18

FOLDOUT FRAME
B

FOLDOUT FRAME
B

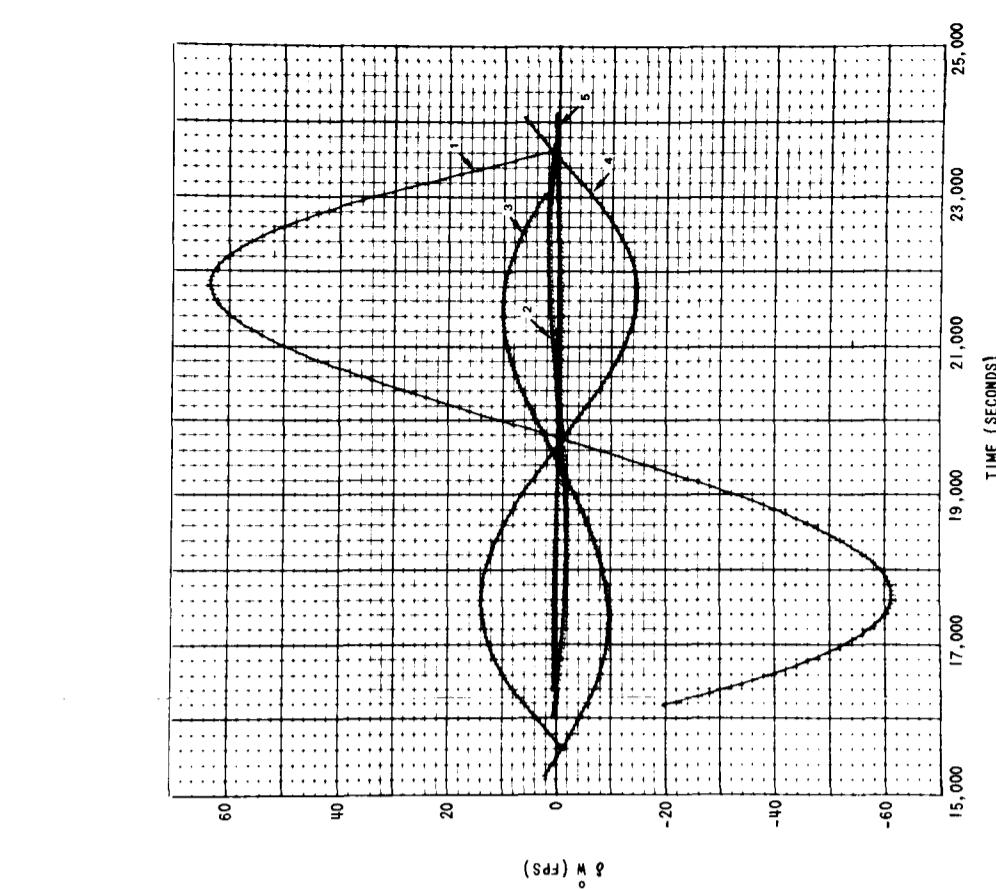
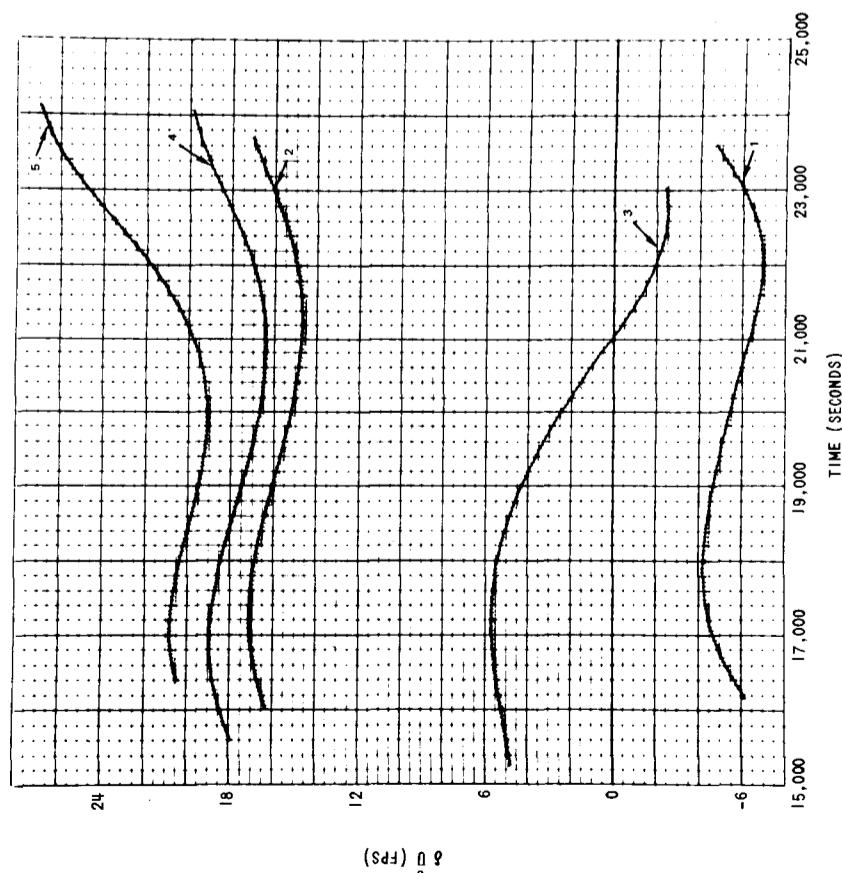
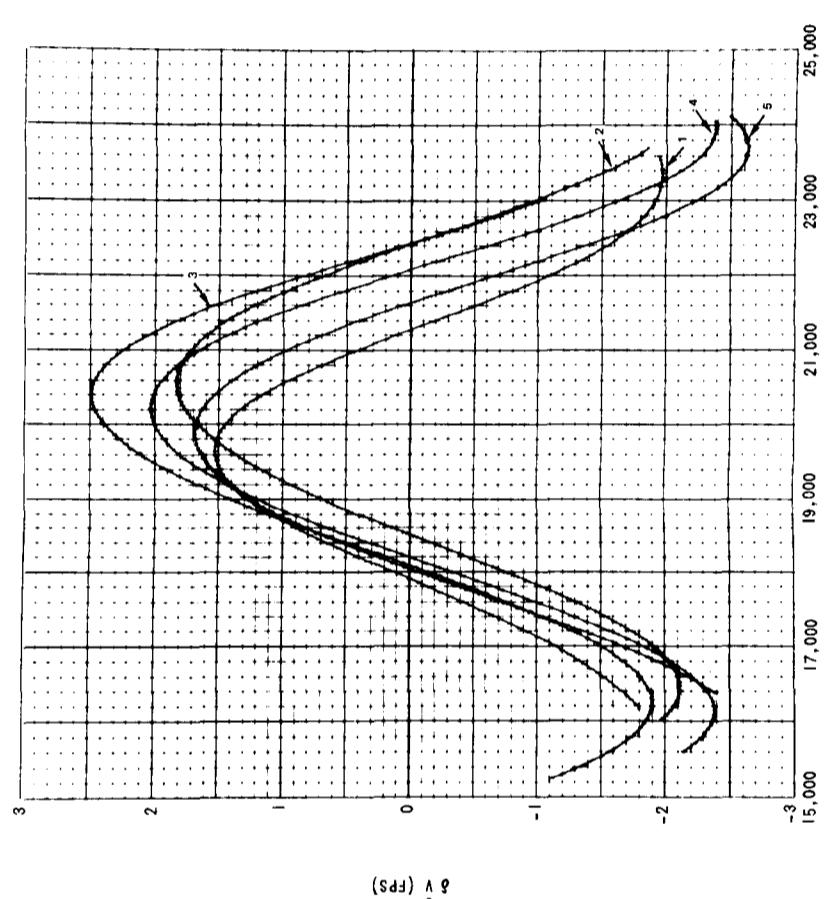


FIGURE 19



FOLDOUT FRAME
A

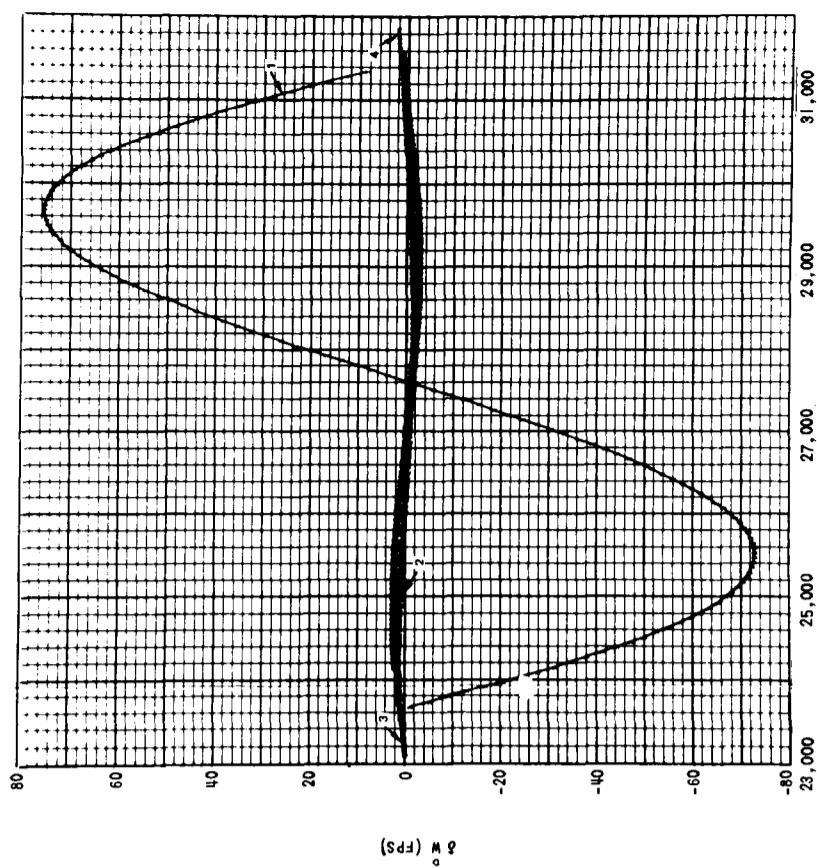


FIGURE 20

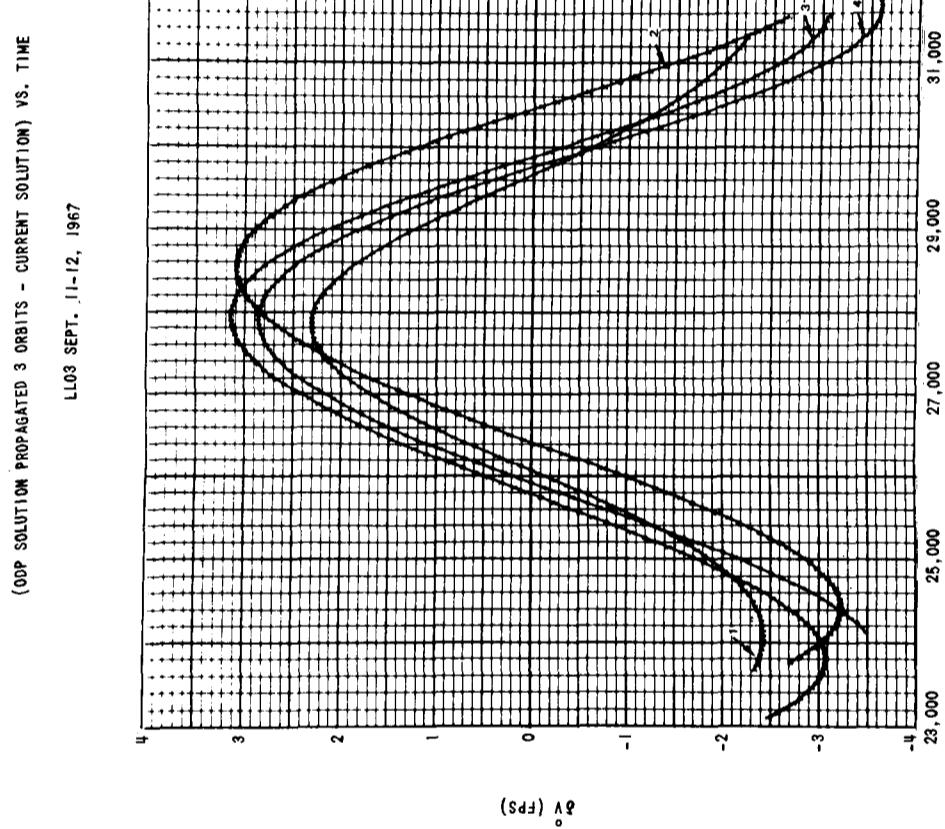
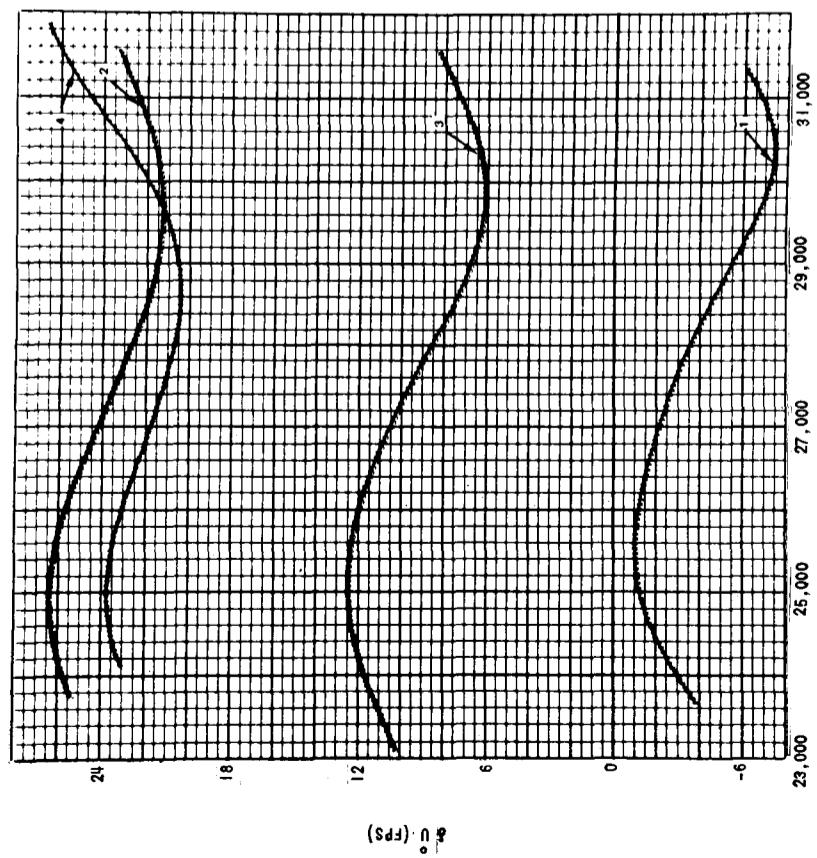


FIGURE 20



FOLDOUT FRAME

B

FOLDOUT FRAME

B

FOLDOUT FRAME

B

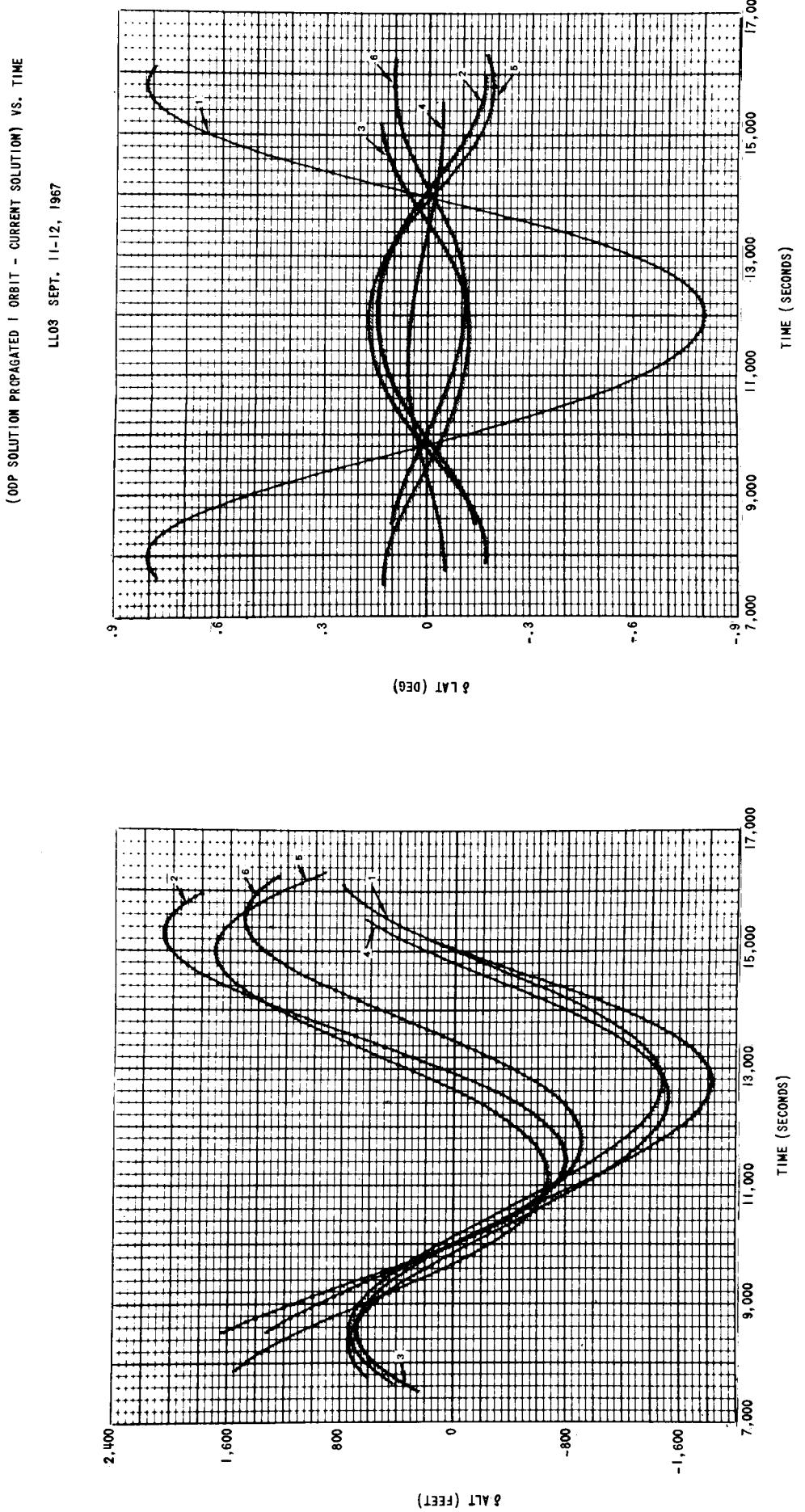


FIGURE 2I

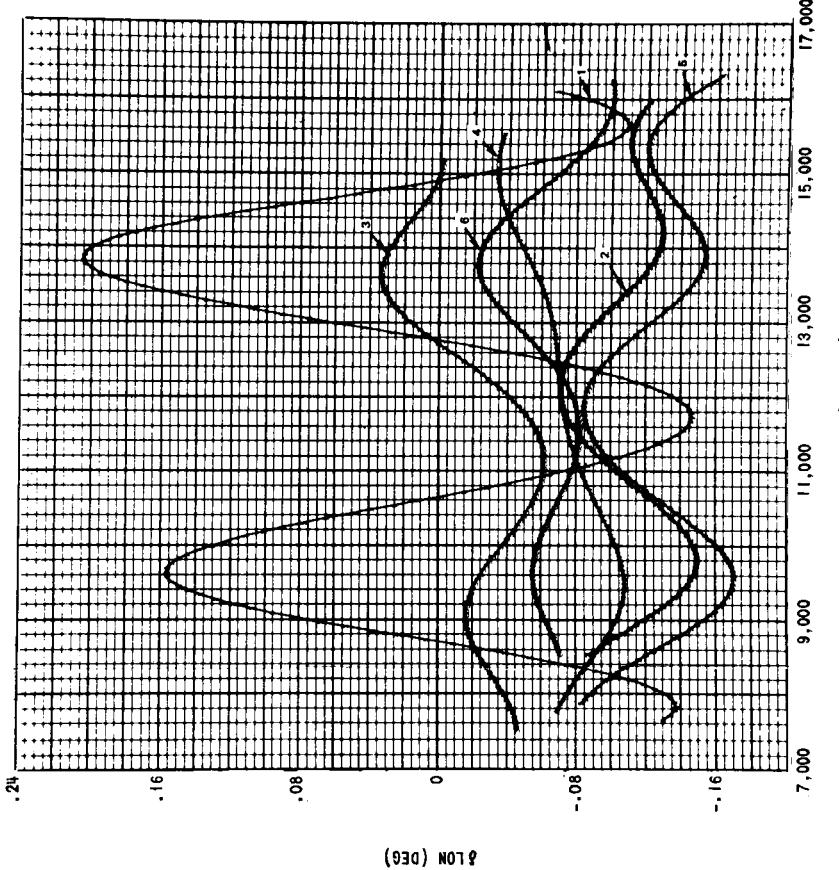
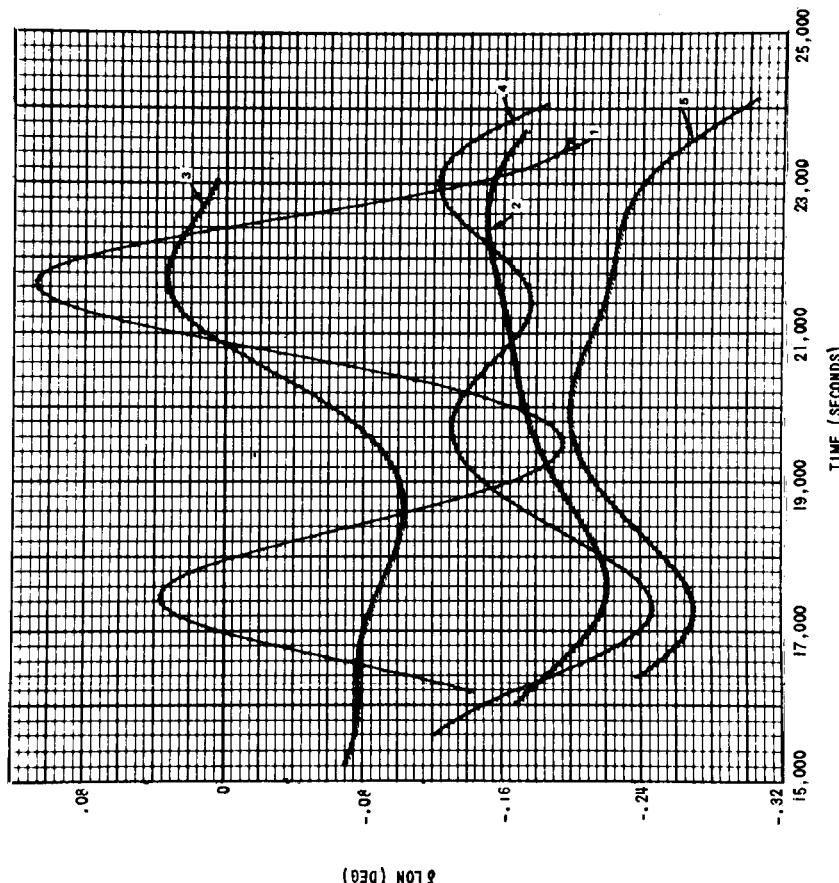


FIGURE 2J

FOLDOUT FRAME

A

FOLDOUT FRAME B



(ODP SOLUTION PROPAGATED 2 ORBITS - CURRENT SOLUTION) VS. TIME
LL03 SEPT. 11-12, 1967

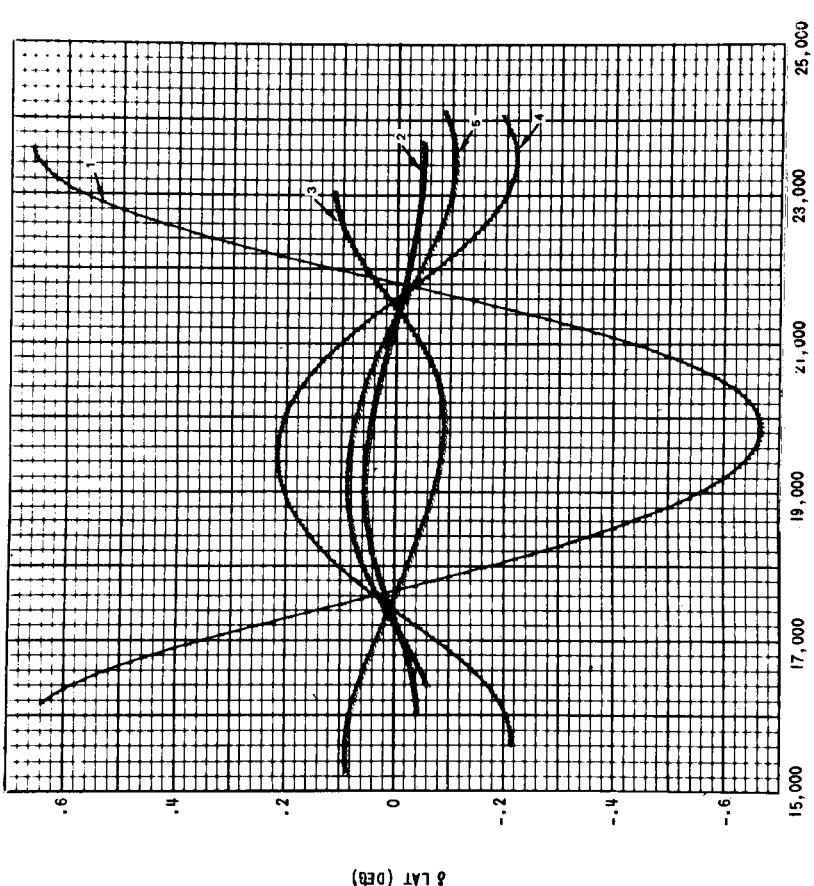
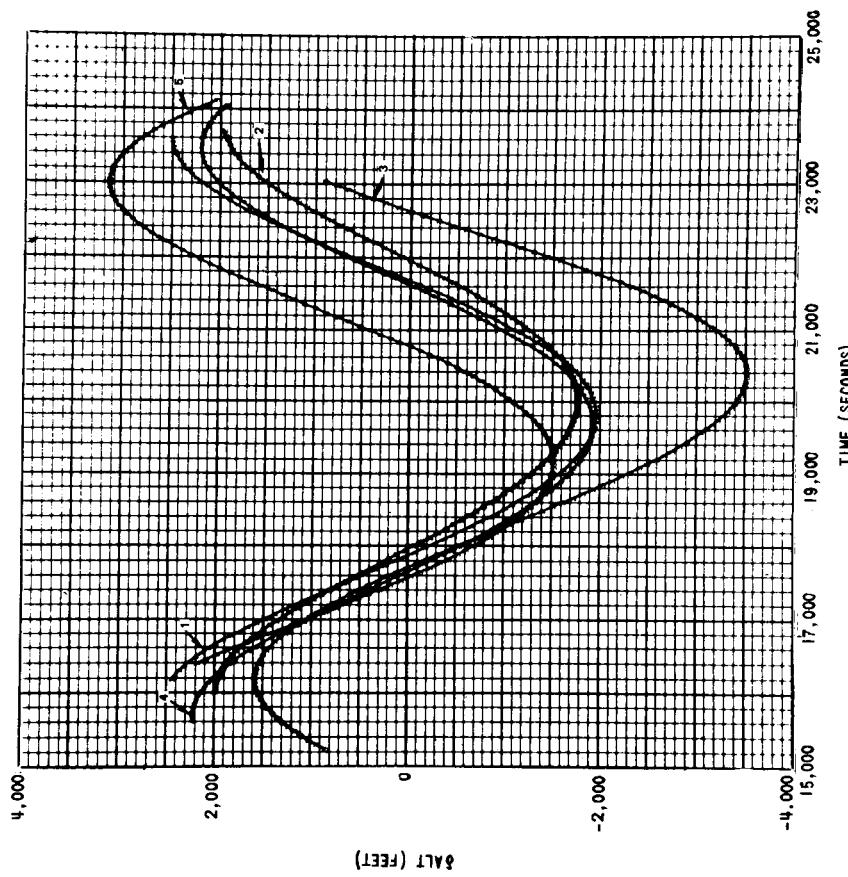


FIGURE 22



FOLDOUT FRAME H

FOLDOUT FRAME
B

(ODP SOLUTION PROPAGATED 3 ORBITS - CURRENT SOLUTION) VS. TIME

LLO3 SEPT. 11-12, 1967

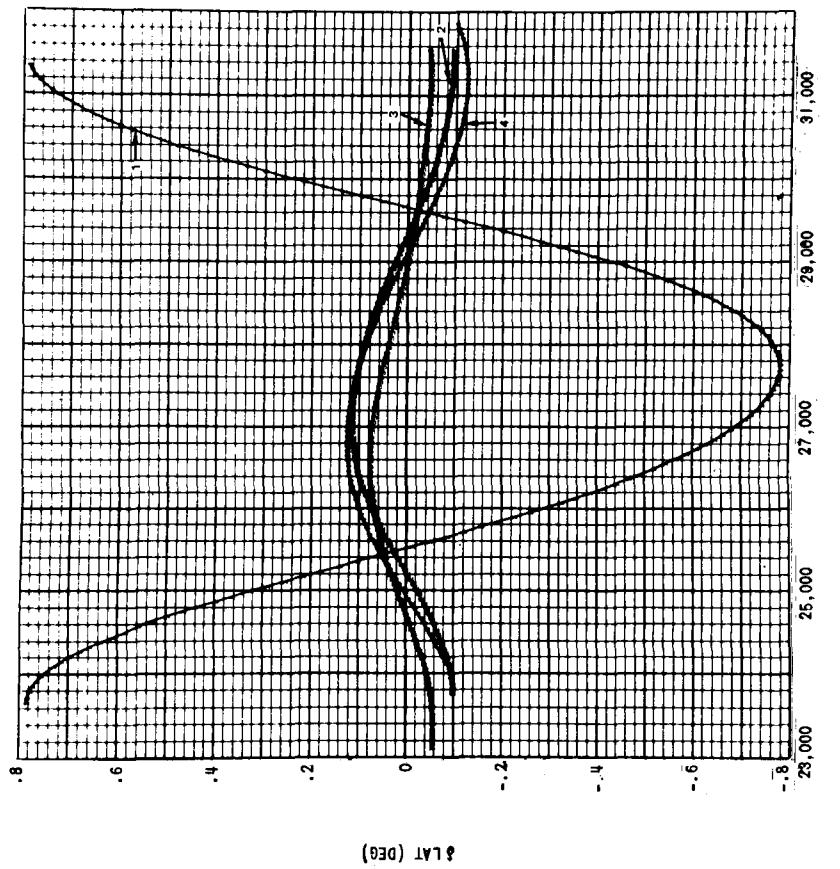
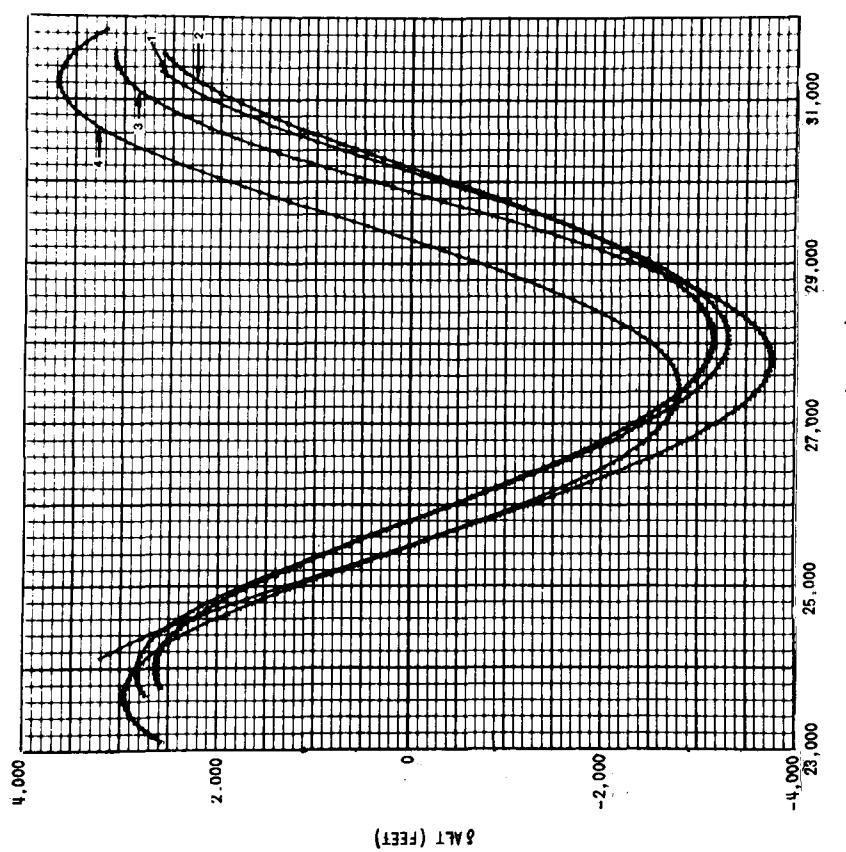


FIGURE 23



FOLDOUT FRAME
D

(ODP SOLUTION PROPAGATED / ORBIT - CURRENT SOLUTION) VS. TIME
LL03 OCT. 5-6, 1967

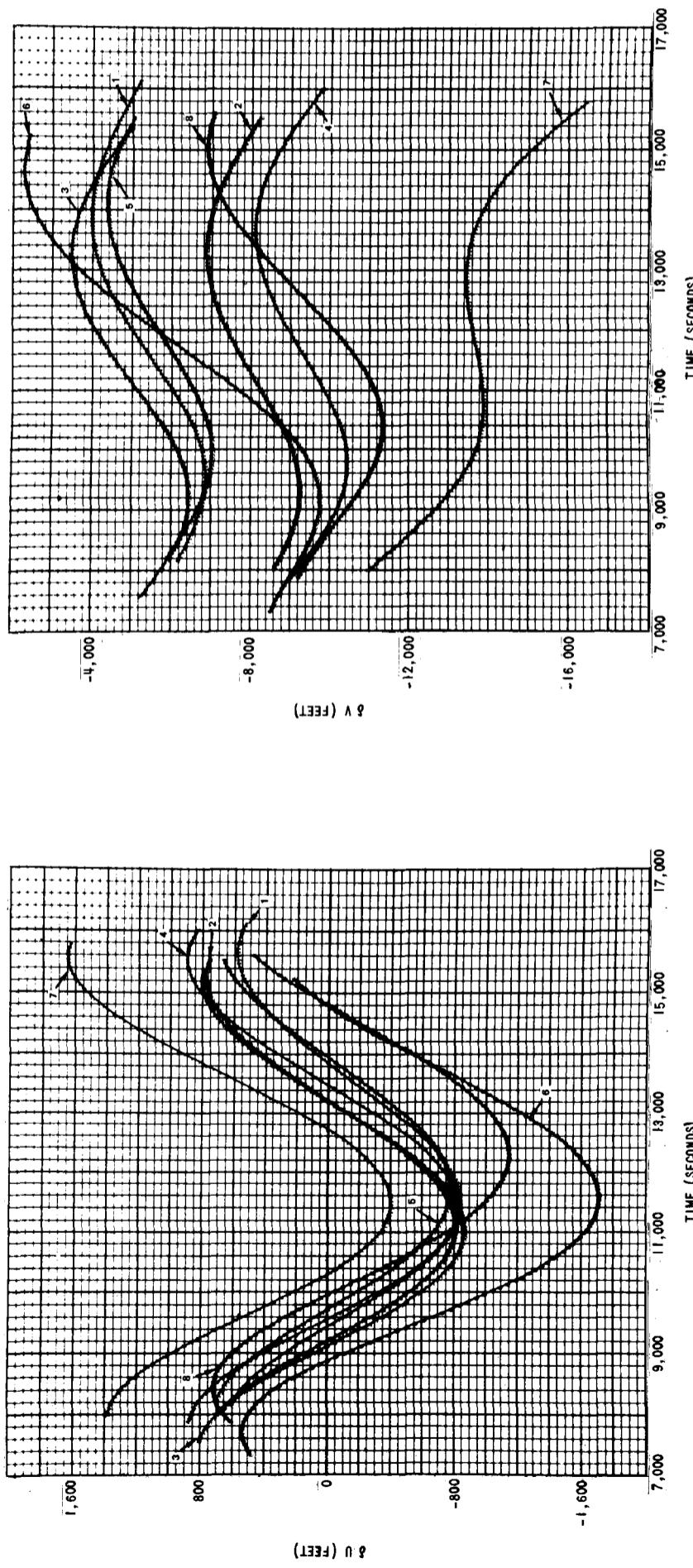


FIGURE 24

FOLDOUT FRAME A

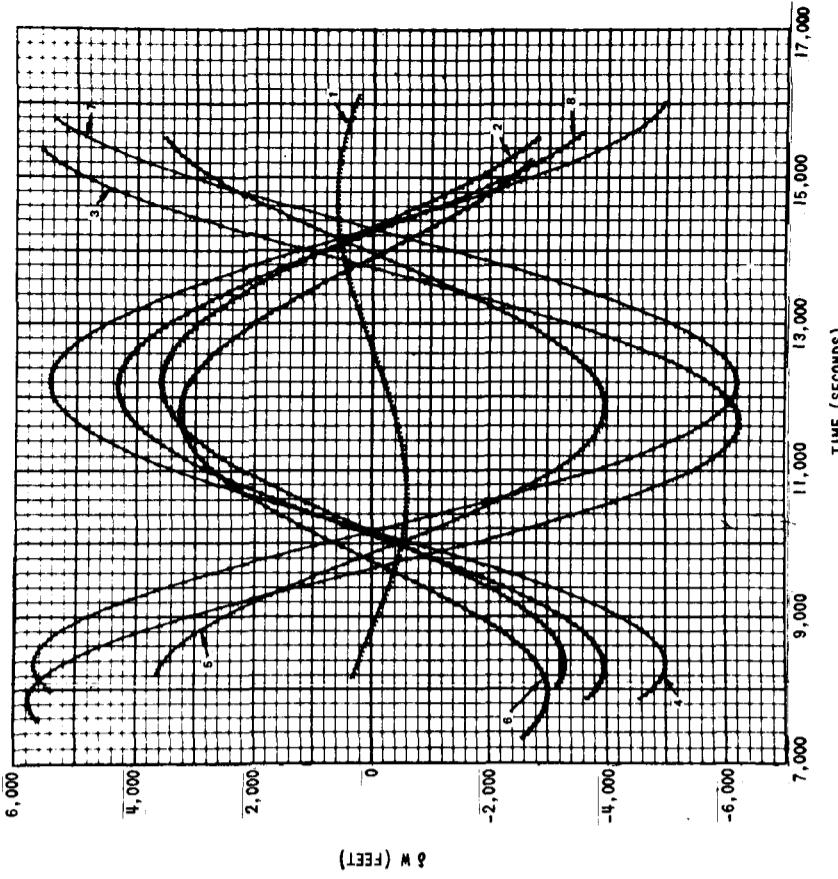


FIGURE 24

FOLDOUT FRAME B

FOLDOUT FRAME
B

(ODP SOLUTION PROPAGATED 2 ORBITS - CURRENT SOLUTION) VS. TIME

LL03 OCT. 5-6, 1967

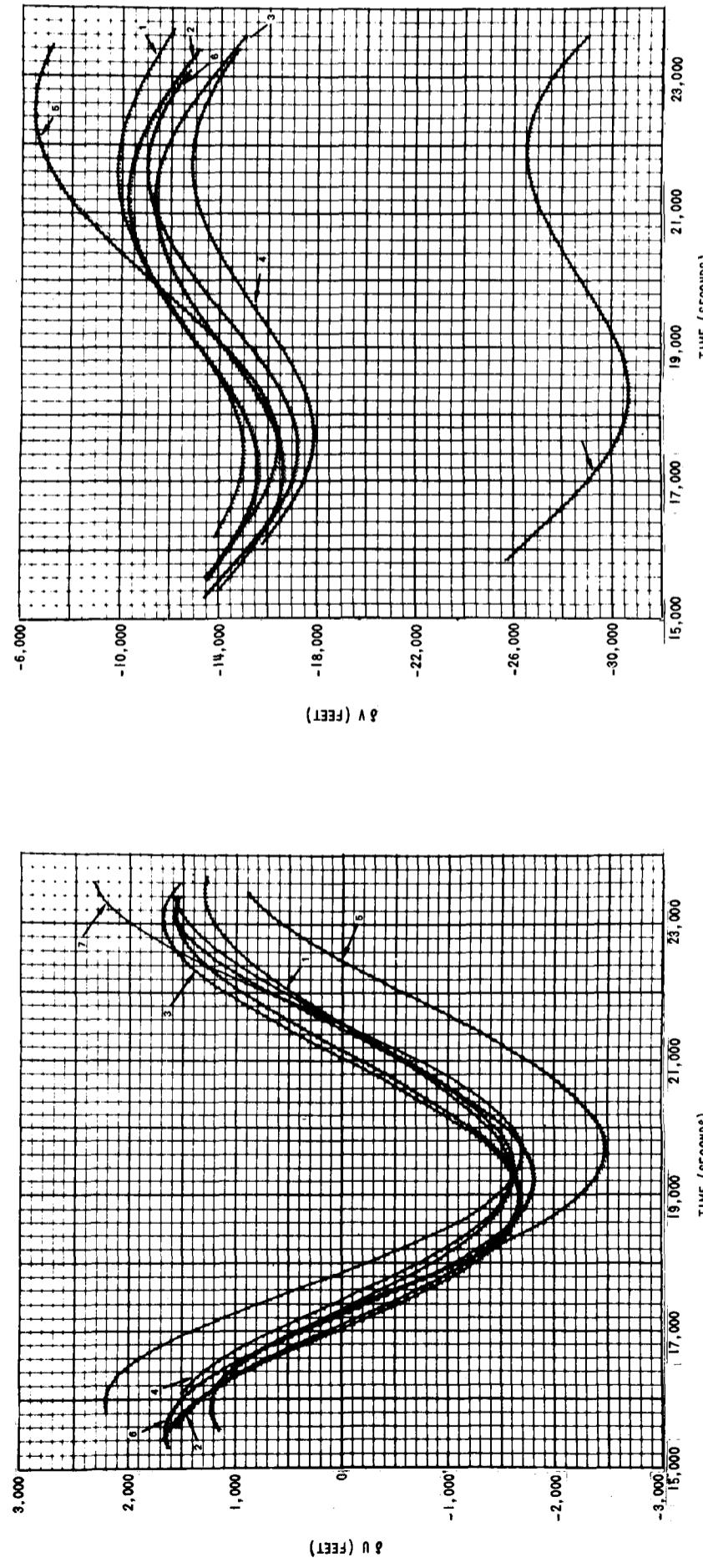
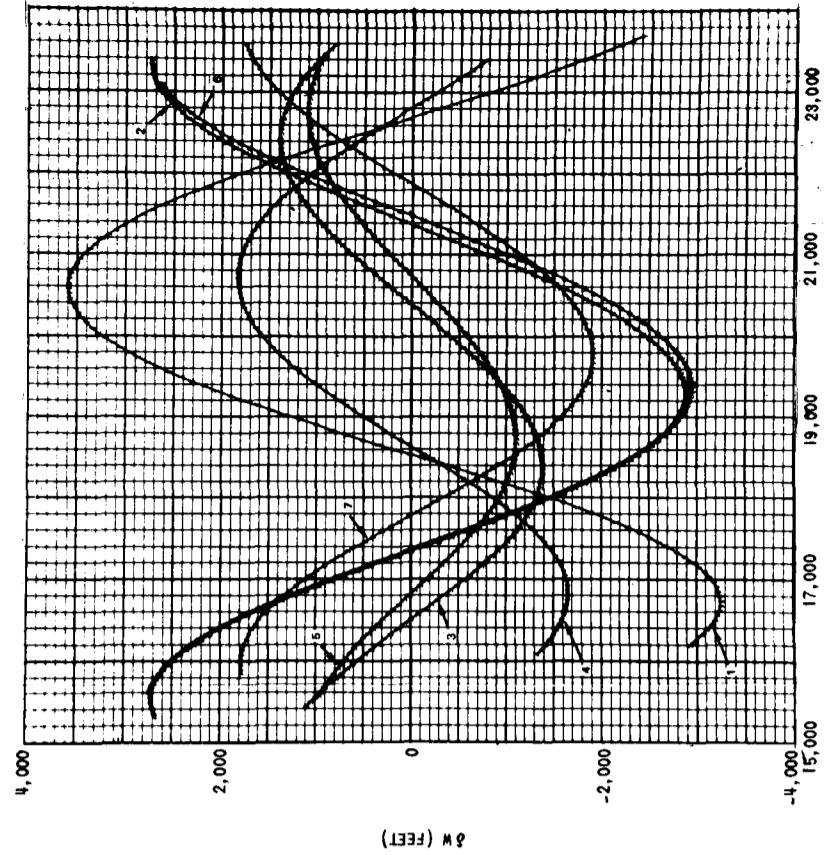


FIGURE 25

FOLDOUT FRAME
C



TIME (SECONDS)

δV (FEET)

4,000

2,000

0

-2,000

-4,000

15,000 17,000 19,000 21,000 23,000

TIME (SECONDS)

δW (FEET)

4,000 2,000 0 -2,000 -4,000

15,000 17,000 19,000 21,000 23,000

TIME (SECONDS)

FOLDOUT FRAME
B

FOLDOUT FRAME
B

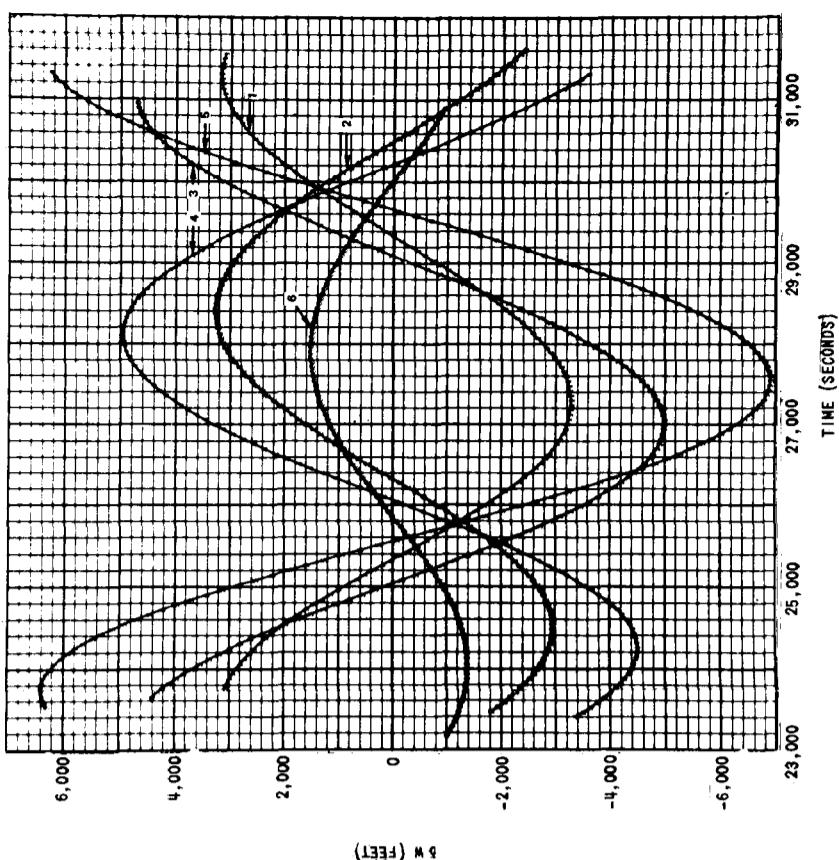
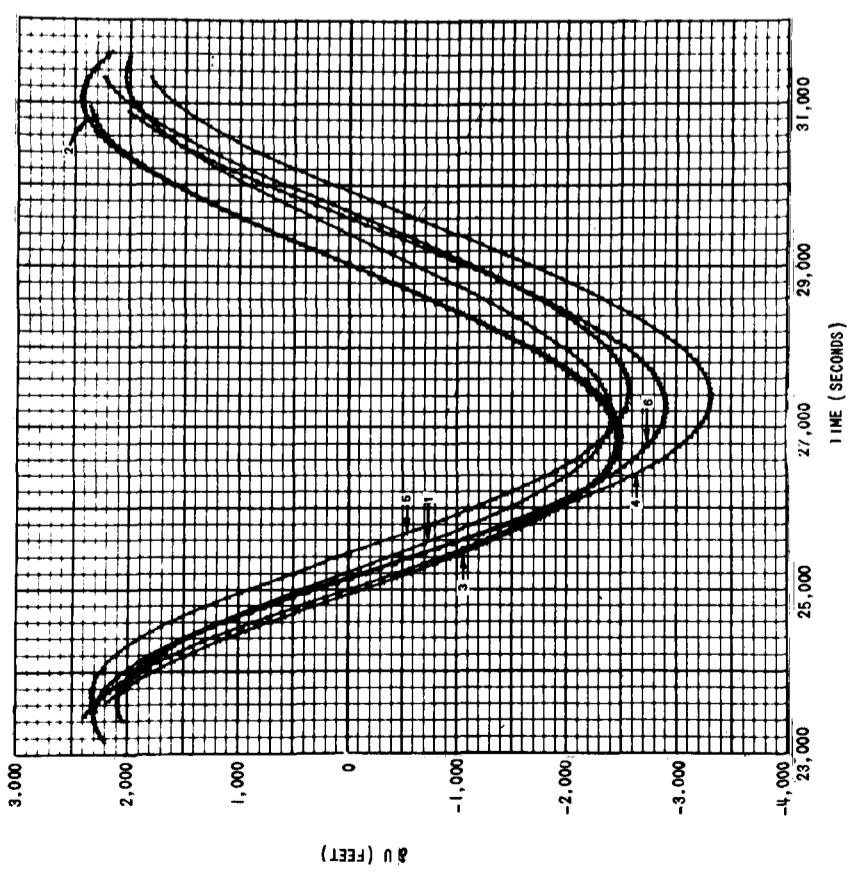
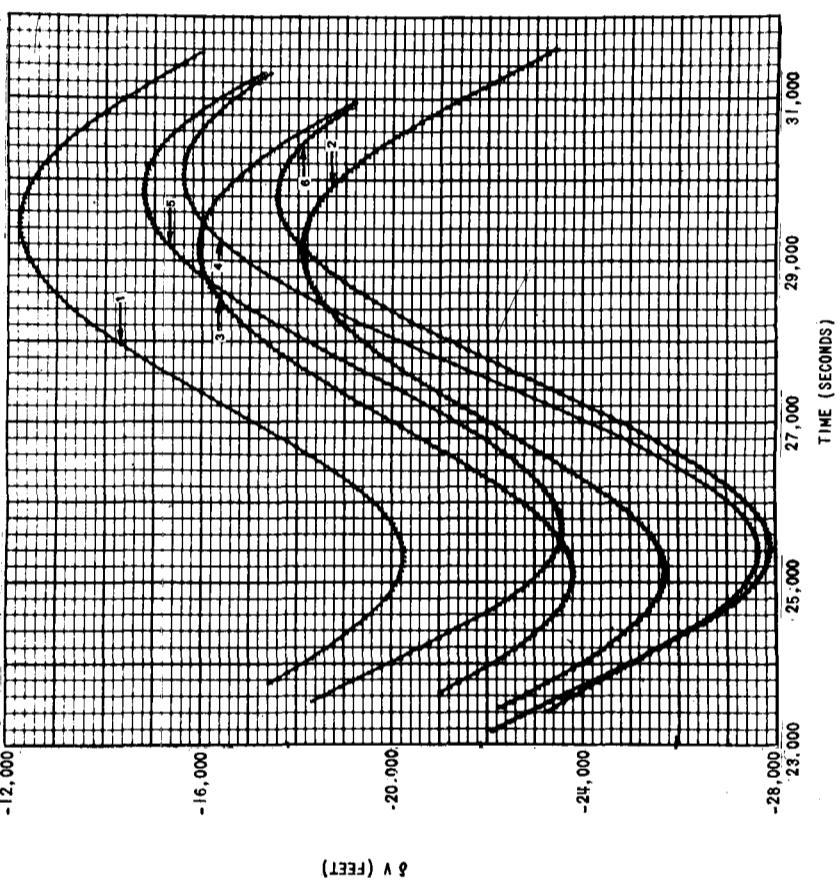


FIGURE 26

(ODP SOLUTION PROPAGATED 3 ORBITS - CURRENT SOLUTION) VS. TIME
LL03 OCT. 5-6, 1967



FOLDOUT FRAME
D.

(ODP SOLUTION PROPAGATED | ORBIT - CURRENT SOLUTION) VS. TIME
LL03 OCT. 5-6, 1967

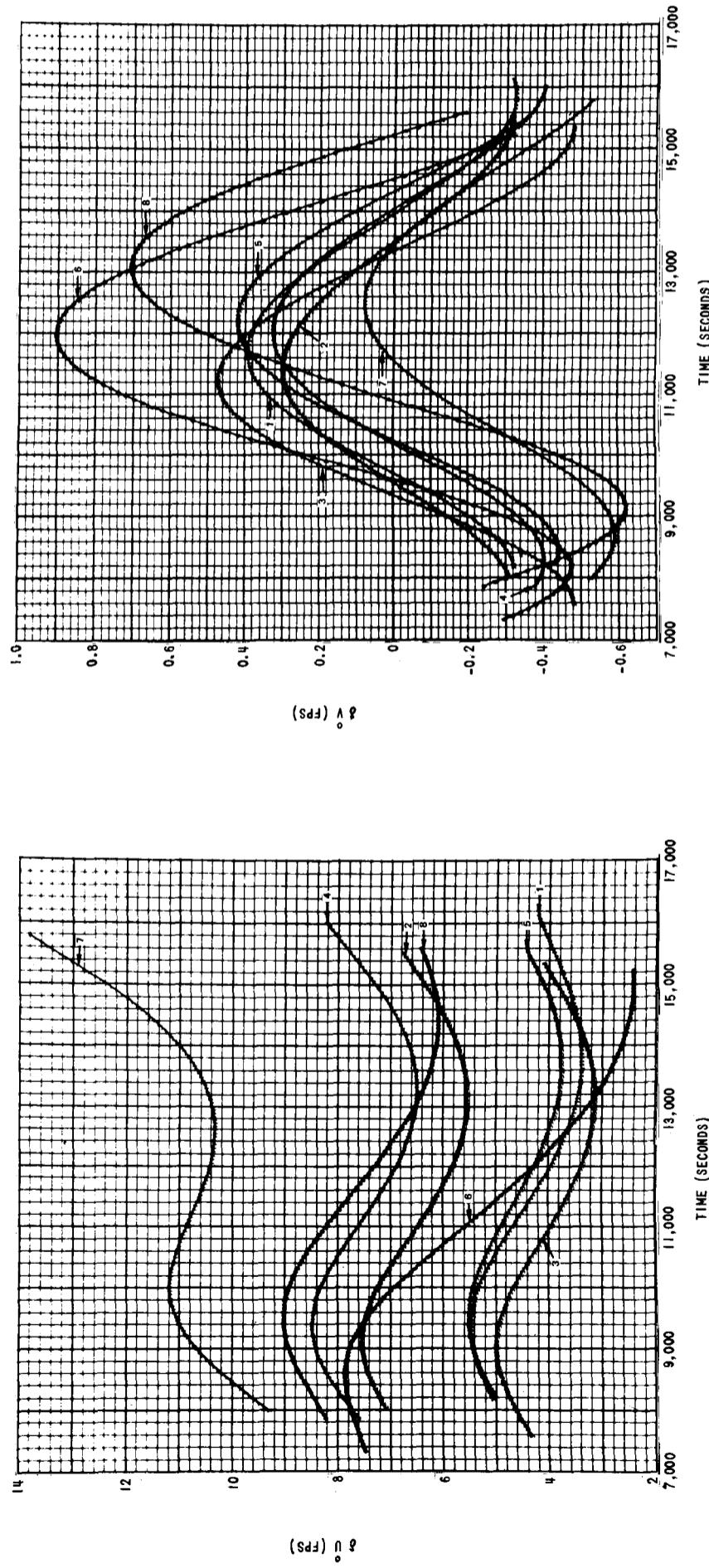


FIGURE 27

FOLDOUT FRAME
A

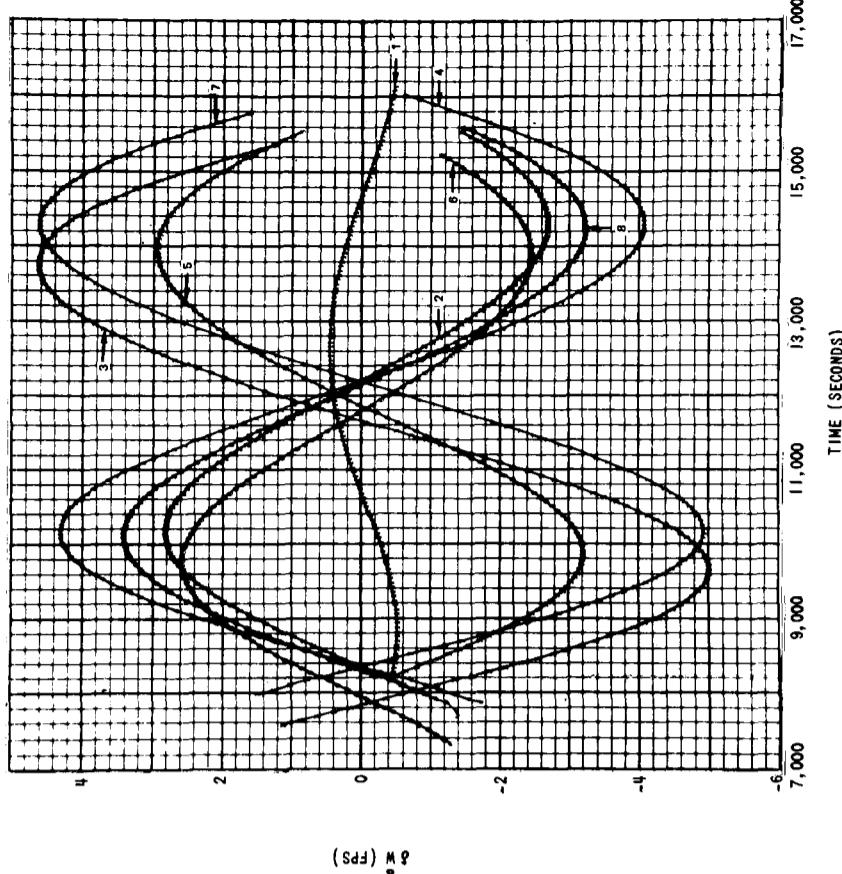
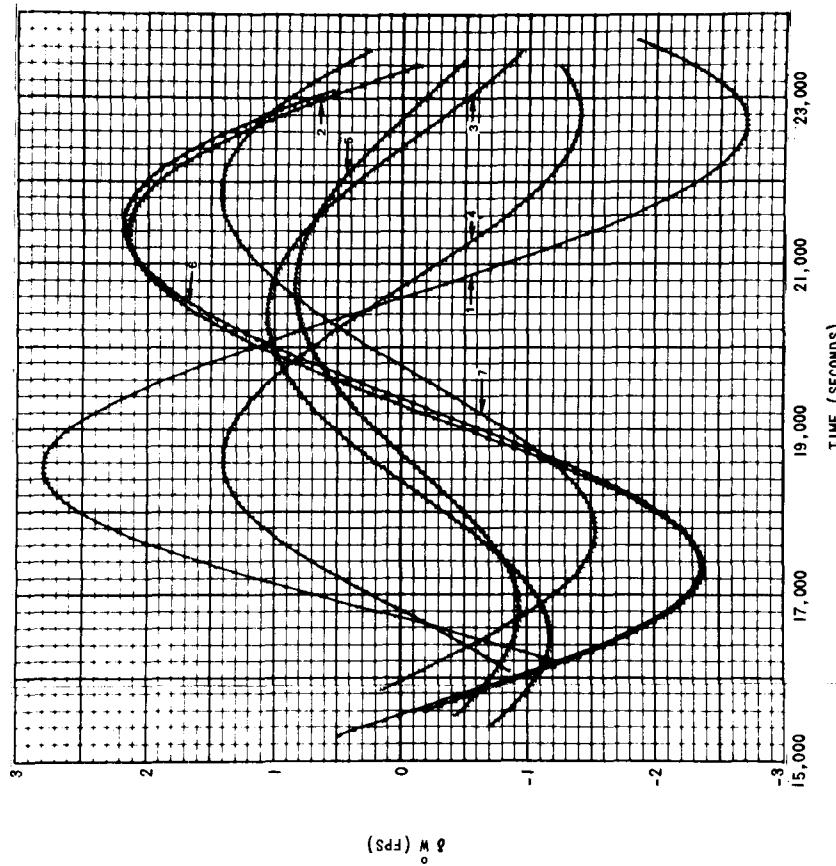


FIGURE 26

FOLDOUT FRAME
B

B
FOLDOUT FRAME



(ODP SOLUTION PROPAGATED 2 ORBITS - CURRENT SOLUTION) VS. TIME
LL03 OCT. 5-6, 1967

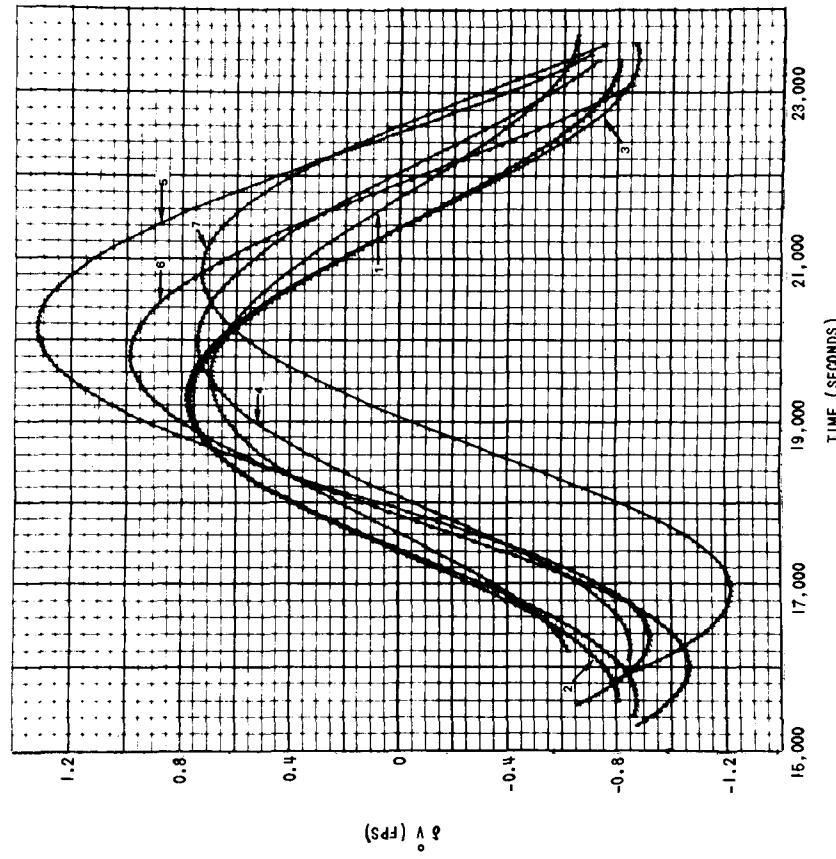
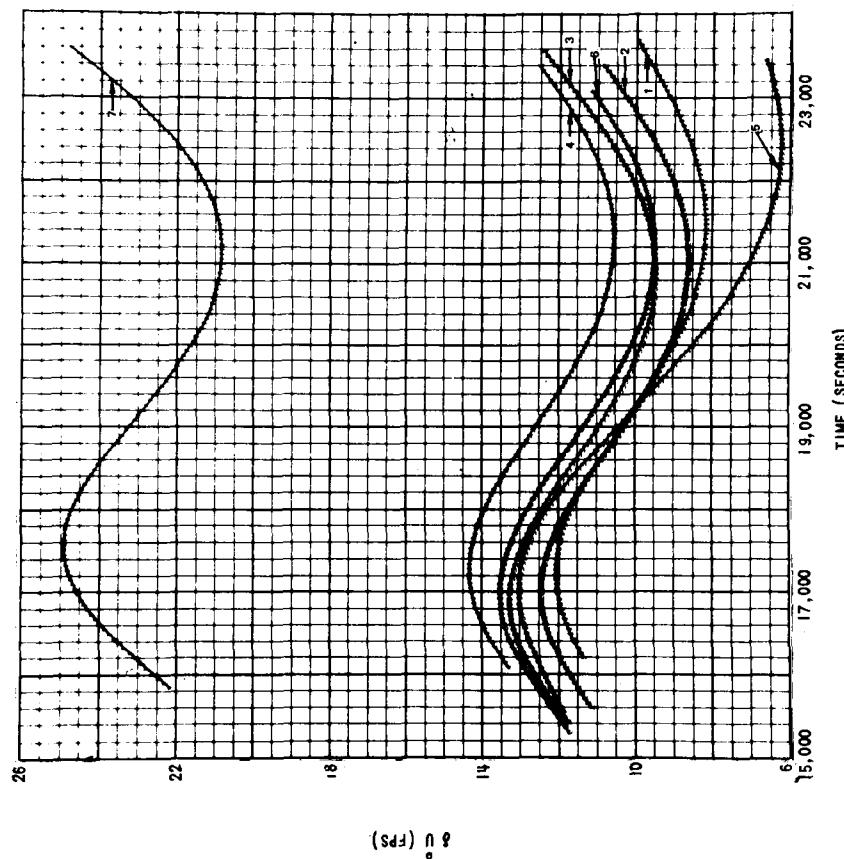


FIGURE 28



FOLDOUT FRAME
A

FOLDOUT FRAME

B.

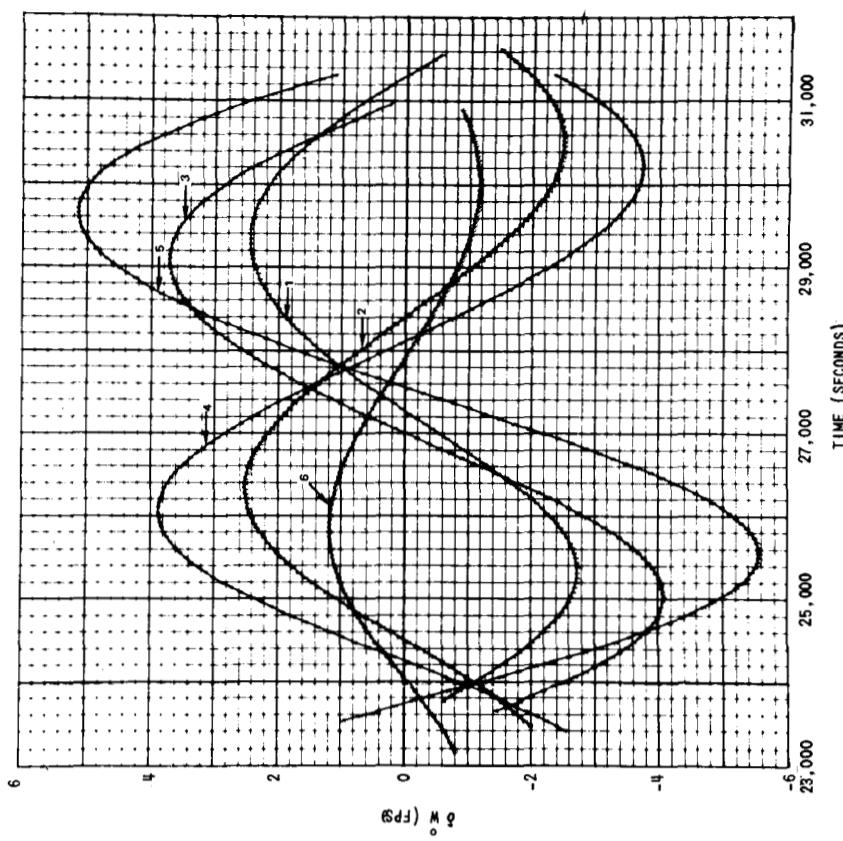
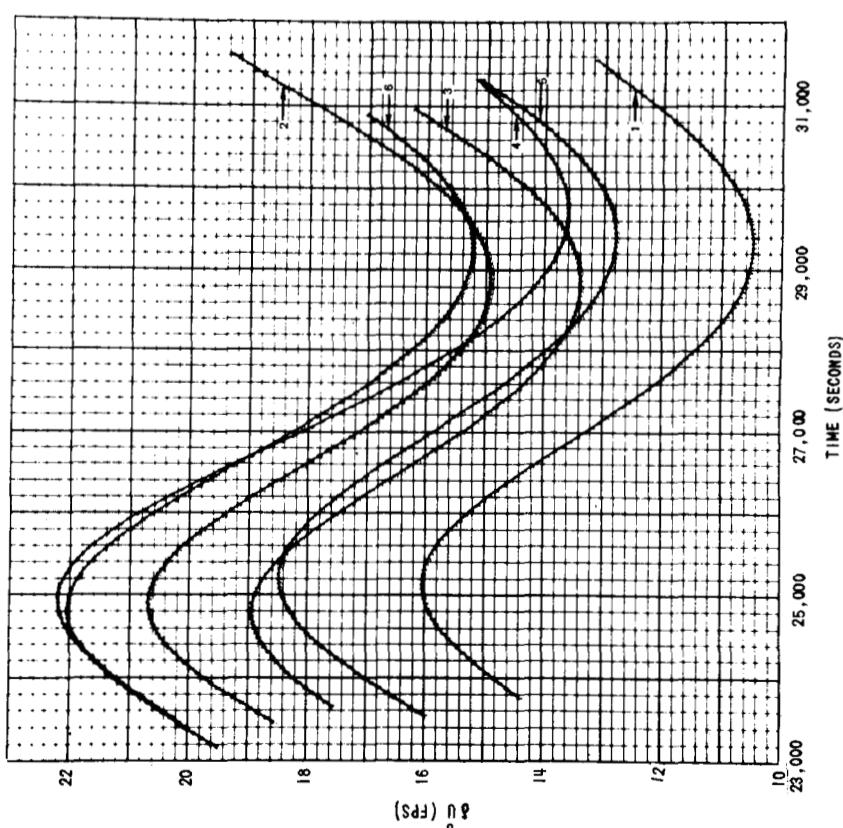
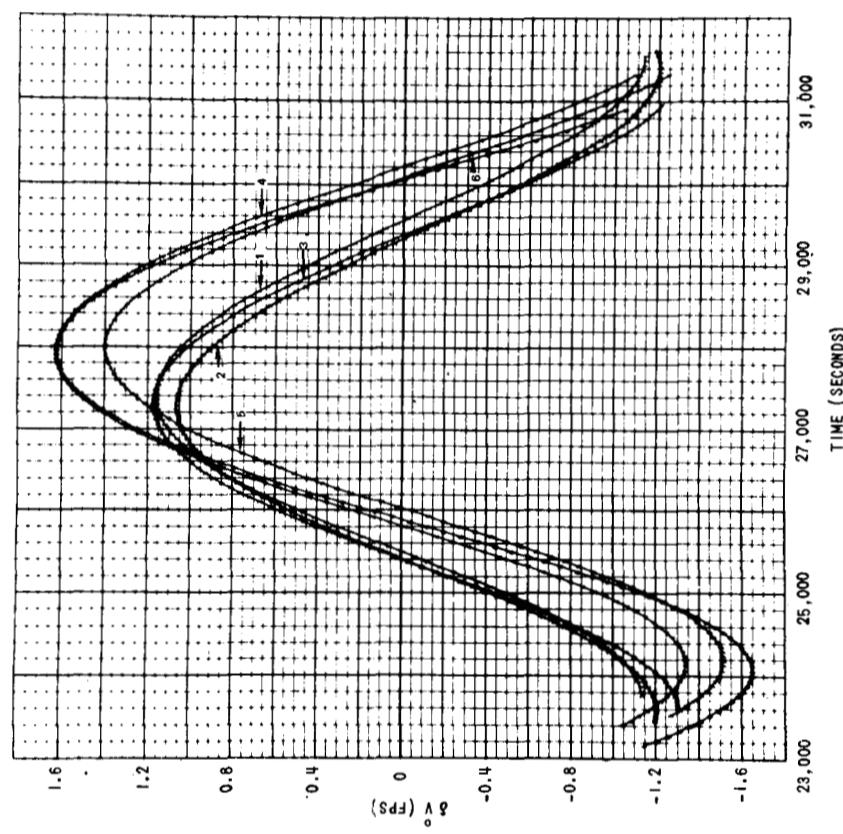


FIGURE 29

(ODP SOLUTION PROPAGATED 3 ORBITS - CURRENT SOLUTION) VS. TIME
LL03 OCT. 5-6, 1967



FOLDOUT FRAME

A.

FOLDOUT FRAME
B.

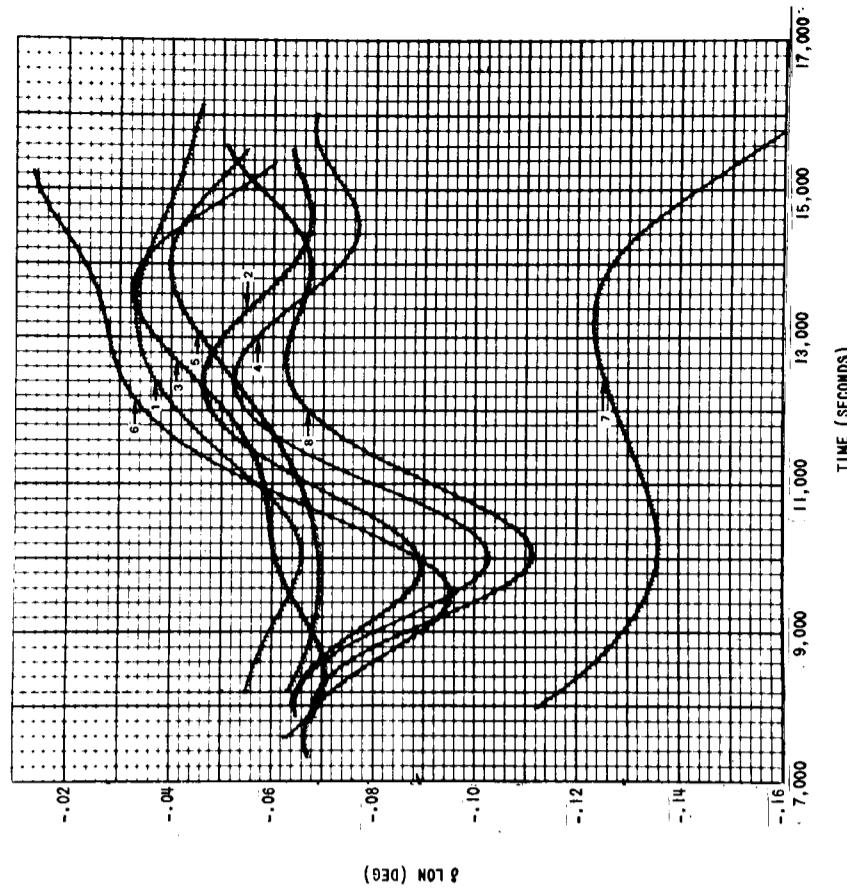


FIGURE 30

(ODP SOLUTION PROPAGATED / ORBIT - CURRENT SOLUTION) VS. TIME
LL03 OCT. 5-6. 1967

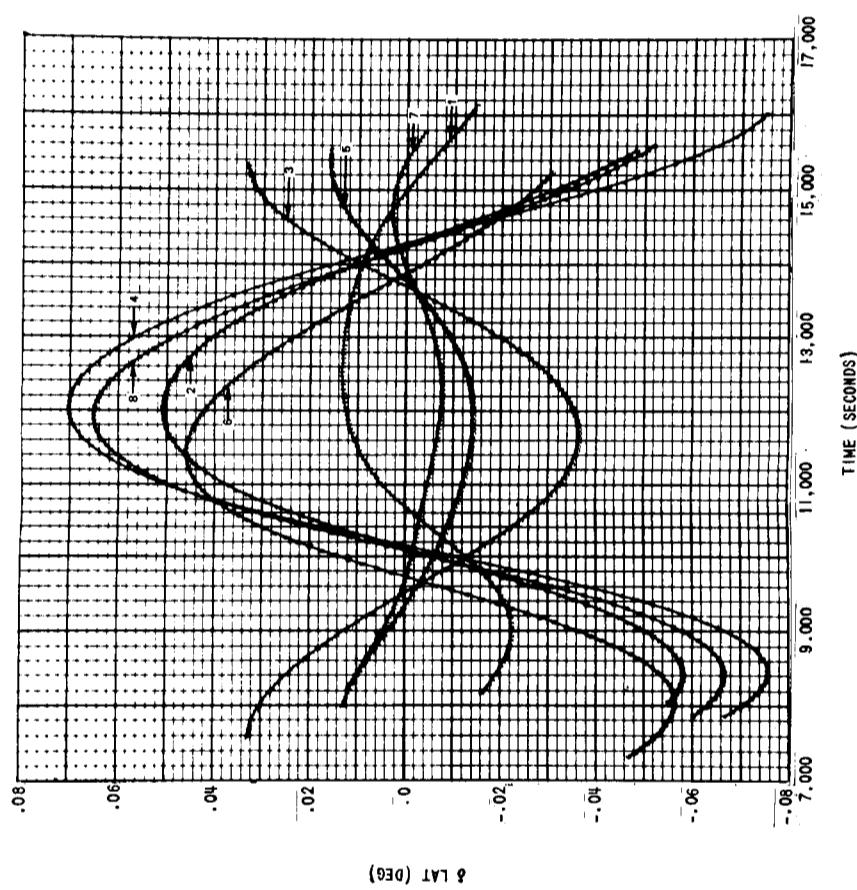


FIGURE 30

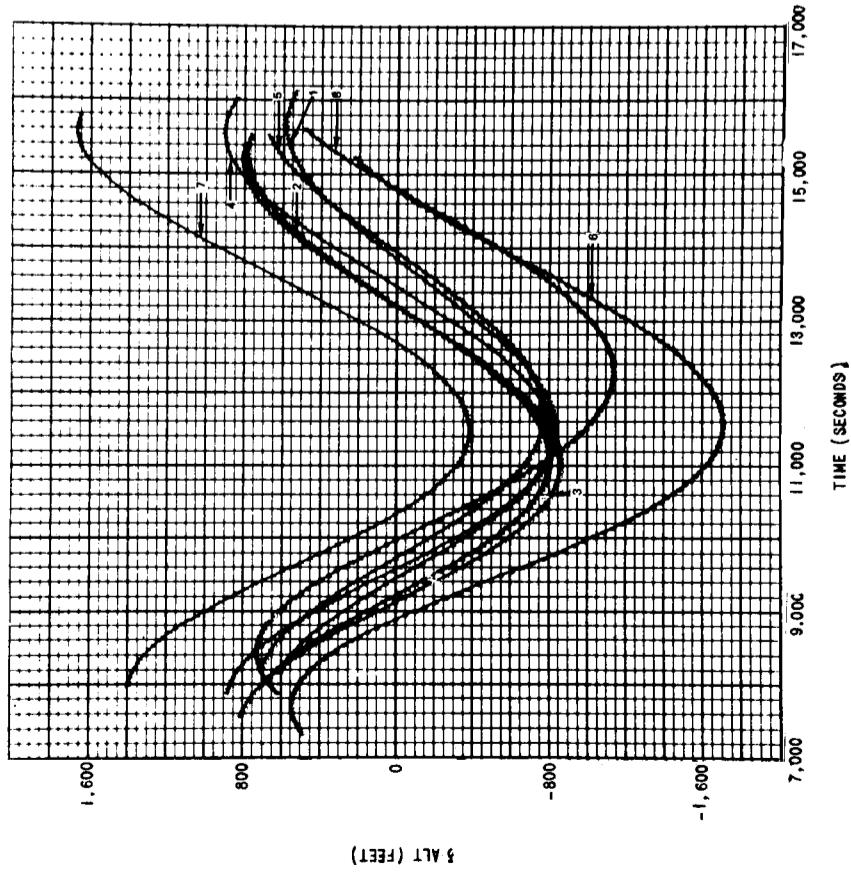


FIGURE 30

FOLDOUT FRAME
D.

FOLDOUT FRAME

B.

TIME (SECONDS)

$\delta \text{ LAT}$ (DEG)

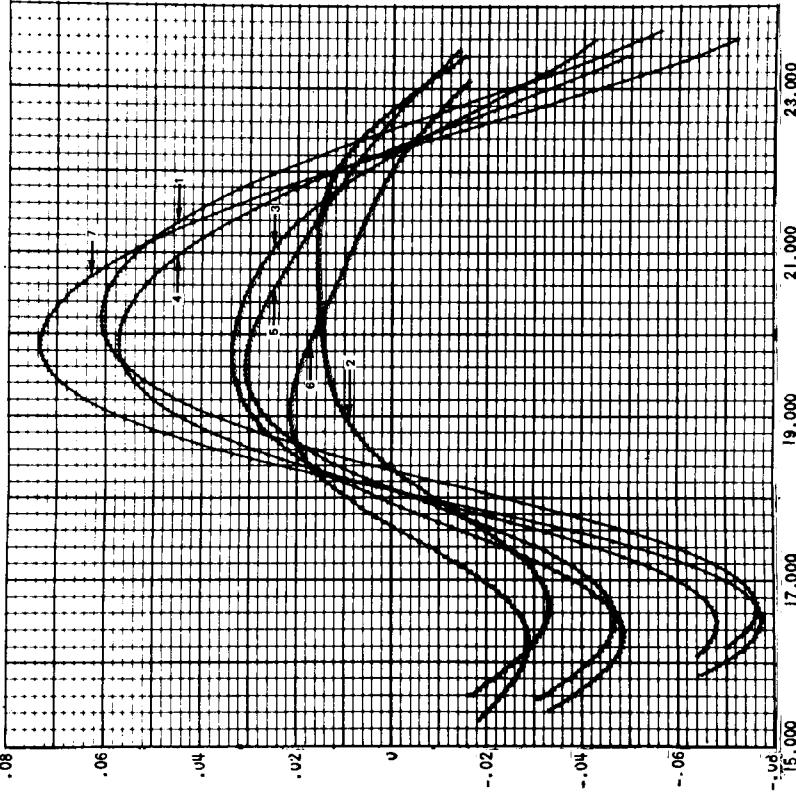


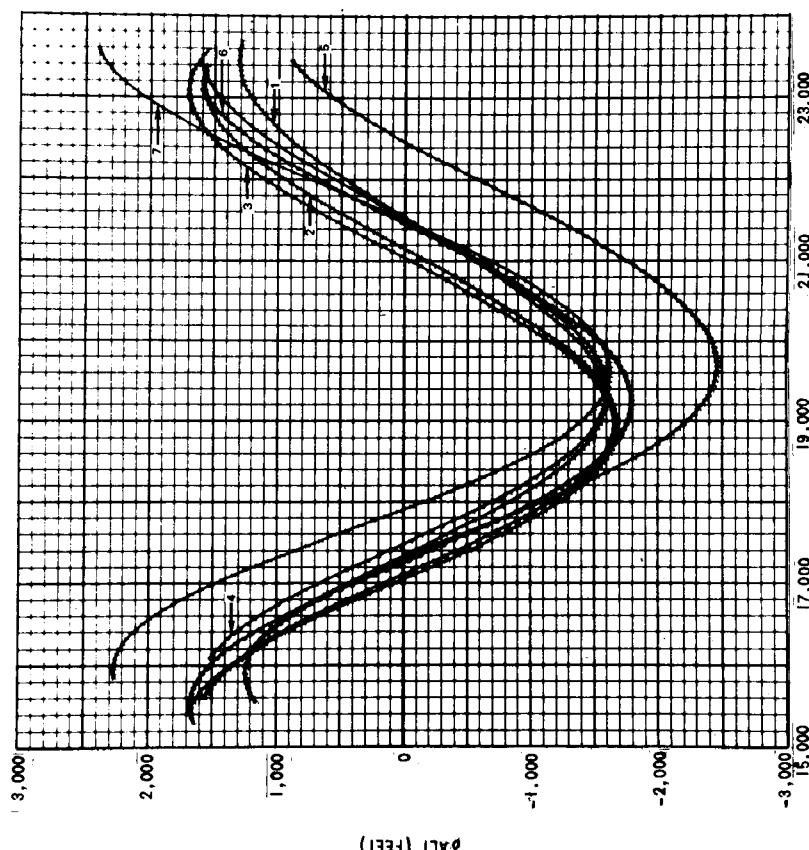
FIGURE 31

FOLDOUT FRAME

D.

TIME (SECONDS)

$\delta \text{ ALT}$ (FEET)



(ODP SOLUTION PROPAGATED 2 ORBITS - CURRENT SOLUTION) VS. TIME
LL03 OCT. 5-6, 1967

(ODP SOLUTION PROPAGATED 3 ORBITS - CURRENT SOLUTION) VS. TIME
LL03 OCT. 5-6, 1967

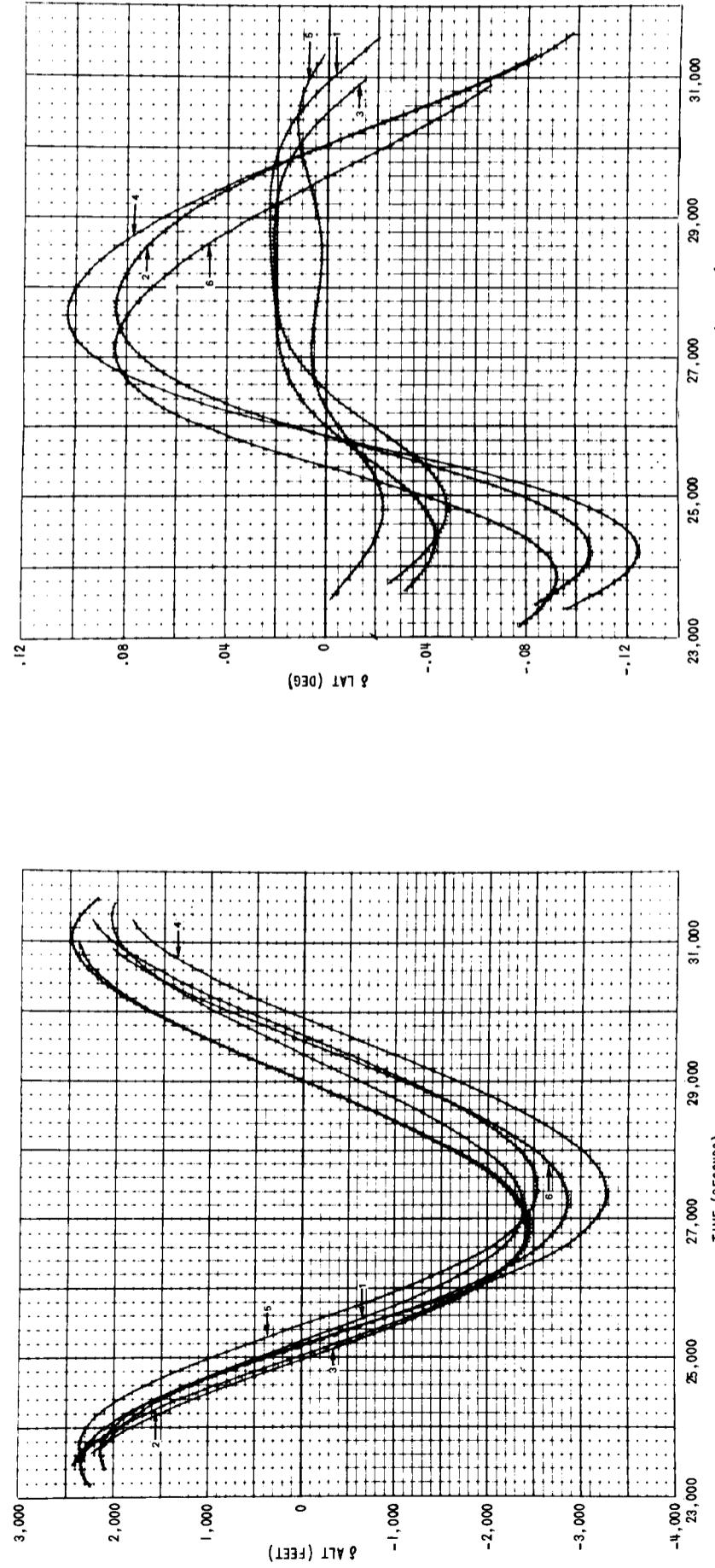
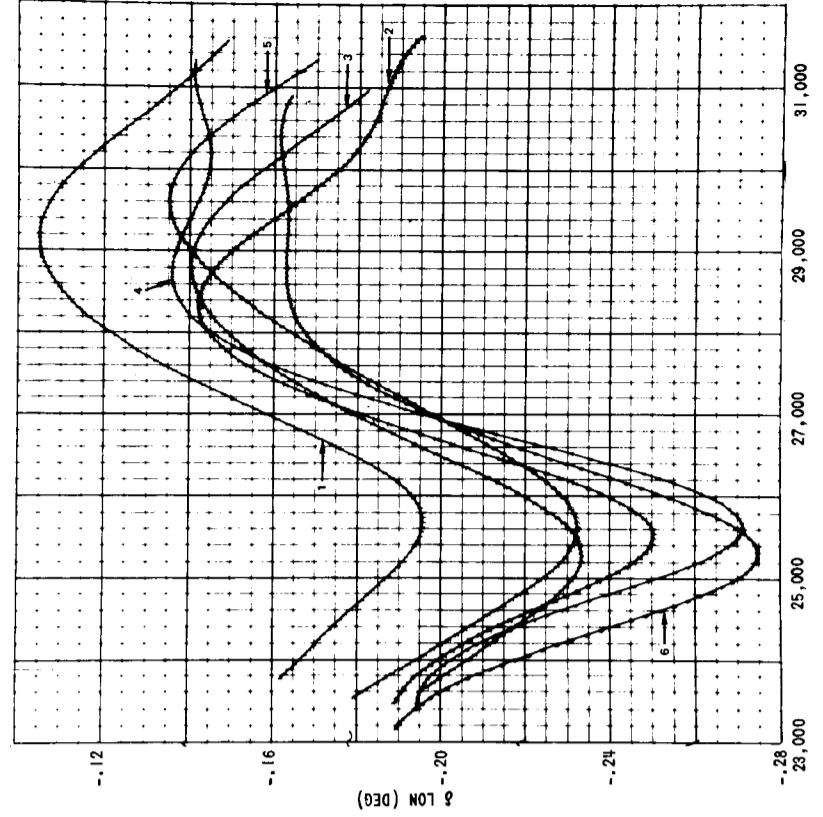


FIGURE 32

FOLDOUT FRAME

FOLDOUT FRAME

(D)



TIME (SECONDS)

FOLDOUT FRAME

(B)

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